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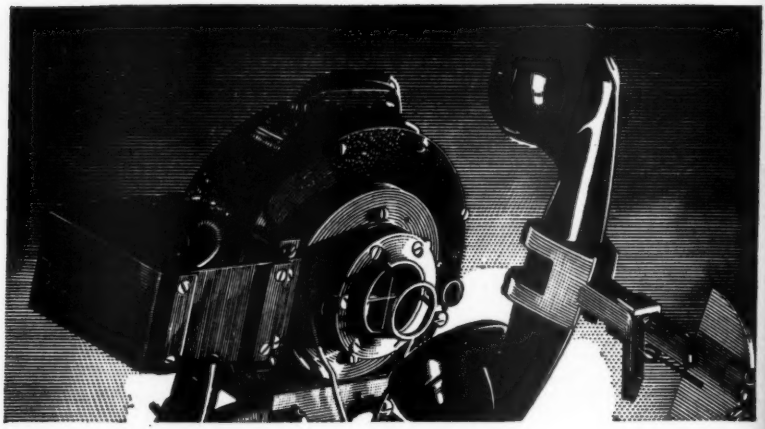

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PROGRESS IN ENGINEERING DEFENSE TRAINING

By ROY A. SEATON *

Very substantial progress has been made in the Engineering Defense Training Program being carried on under the direction of the U. S. Office of Education since I reported the beginning of this training in the December, 1940 issue of the JOURNAL OF ENGINEERING EDUCATION. Up to December 30, 1940, authorization had been given to 91 engineering colleges, located in 44 States, the District of Columbia, and Puerto Rico, to begin instruction in a total of 344 short engineering courses of college grade. Instruction had already begun in some of these courses but in most of them instruction is expected to start early in January, 1941. All of these courses are designed to meet the shortage of engineers with specialized training in fields essential to the national defense. Because of the urgency of this need both the U. S. Office of Education and the engineering colleges have been making every possible effort to speed the program.

Some of the Engineering Defense Training courses that have been authorized are to provide pre-employment training, while others are for the upgrading of workers already employed in defense industries and Governmental defense agencies. The extremely rapid expansion of these industries and agencies creates a need for great numbers of additional men qualified for supervisory and technical positions. In many instances such qualified men can be secured most readily by giving additional training to men now employed in less responsible positions in the industry or agency and already familiar with its products or functions. In other cases new men must be trained and brought in from outside.

Some of the courses are to be given in the daytime and others at night. Many are being set up on an extension service basis in quarters near the industries to be served for the greater convenience of the part-time students. In length the courses vary from a few weeks to about six months, depending upon the content of the course and the amount of time the students have available for study.

Since all instruction in these courses is to be of college grade, high-school graduation is the minimum requirement for entrance. Much higher educational qualifications are necessary for the more

* Dean of the Division of Engineering and Architecture, Kansas State College, absent on leave to serve as Director of Engineering Defense Training in the U. S. Office of Education.

advanced courses. Each school has determined the admission requirements for each of its courses and is to be responsible for the qualifications of students admitted to the courses.

The cost of instruction in the courses will be paid by the Federal Government but students will be required to provide their own subsistence, textbooks, and supplies. No tuition or other fees are to be required by students, but they may be required to make customary deposits to assure proper use and return of institutional property. The college placement bureaus will assist students who complete the pre-employment courses to find jobs and will enlist the aid of the U. S. Civil Service Commission and the State and Federal Employment Services in this work.

A list of the Engineering Defense Training courses already authorized and of the institutions that are to offer them is given below. Additional authorizations are being issued daily.

ENGINEERING DEFENSE TRAINING PROGRAM

Courses Approved to December 30, 1940

	Alabama
Alabama Polytechnic Institute Auburn	Construction Engineering Engineering Drawing Engineering Economy Industrial Relations Machine Design Marine Engineering Military Highway Engineering Naval Architecture Production Engineering Surveying Tool Engineering
University of Alabama University	Correlation Course for Ordnance Inspectors Industrial Organization and Management, Time and Motion Study Industrial Practice, Cast Iron Pipe and Fittings Industry Industrial Practice, Electric Power Industry Industrial Practice, Steel Industry Industrial Safety and Safety Administration Mechanics and Strength of Materials Mechanisms and Elementary Machine Design Physical Metallurgy and Metallurgy of Iron and Steel Tool and Die Design
	Arkansas
University of Arkansas Fayetteville	Engineering Drawing

	California
California Institute of Technology, Pasadena	Production Engineering Production Supervision Radio and Electronics
University of Southern California, Los Angeles	Materials Inspection and Testing (Unit A) Materials Inspection and Testing (Unit B) Materials Inspection and Testing (Unit C)
	Colorado
Colorado School of Mines Golden	Production of Major Non-Ferrous Metals Theory and Application of Welding
Colorado State College of Agricultural and Mechanical Arts, Fort Collins	Engineering Drawing Machine Design Materials Inspection and Testing
University of Colorado Boulder	Advanced Electronic Instruments Airplane Stress Analysis Engineering Drawing and Machine Design Machine Design Material Testing and Inspection Production Engineering Technology of Heavy Chemicals Industry Theory of Elasticity
University of Denver Denver	Testing of Chemicals and Other Defense Materials
	Connecticut
Yale University New Haven	Applied Mechanical Design Engineering Drawing Inspection of Materials Metallurgy Production Control Welding Supervision
	Delaware
University of Delaware Newark	Motion and Time Analysis
	District of Columbia
George Washington University Washington	Concrete Inspection and Testing Construction Materials, Properties, Tests and Specifications Map Making and Interpretation Radio Communication Ship Construction Structural Steel Design Surface and Aerial Navigation
Howard University Washington	Engineering Drawing
	Florida
University of Florida Gainesville	Engineering Drawing

	Georgia
Georgia School of Technology Atlanta	Construction Materials Engineering Drawing Metal Inspection Textile Testing
	Idaho
University of Idaho Moscow	Design Drafting Engineering Drawing
	Illinois
Bradley Polytechnic Institute Peoria	Engineering Drawing
Illinois Institute of Technology Chicago	Design of Bombproof Shelters Design of Tools and Testing Equipment Diesel Engines Drafting and Elementary Design Industrial Management Inspection Methods Machine Design Metallurgy Production Planning Routing Strength of Materials and Steel Design Structural Designing and Drafting Testing and Inspection of Concrete Testing Methods Time and Motion Study Tool and Fixture Design Welding Engineering
	Indiana
Purdue University Lafayette	Aeronautical Engineering Applications of Electronics Engineering Drafting Explosives Inspection Machine Design Materials Inspection Materials Testing and Inspection (2 courses) Metallurgy Production Engineering (2 courses) Production Supervision (2 courses) Tool Design (2 courses)
Rose Polytechnic Institute Terre Haute	Electrical Communication Engineering Drawing and Machine Design Illuminating Engineering Materials Inspection and Testing Production Engineering
University of Notre Dame South Bend	Chemical Analysis of Metallurgical Materials Production Engineering Physical Metallurgy Tool and Die Design

	Iowa
Iowa State College Ames	Materials Inspection and Testing Tool Engineering
	Kansas
Kansas State College Manhattan	Aeronautical Engineering Engineering Drawing Explosives Materials Inspection and Testing Tool Engineering
University of Kansas Lawrence	Aeronautical Engineering Engineering Drawing Machine Design Materials Inspection and Testing Production Engineering and Supervision
	Kentucky
University of Louisville Louisville	Aerial Photographic Mapping Applied Mechanics (Statics) Elementary Unified Mathematics Ferrous Physical Metallurgy Non-Ferrous Physical Metallurgy Strength of Materials
	Louisiana
Louisiana Polytechnic Institute Ruston	Engineering Drawing
Southwestern Louisiana Institute Lafayette	Engineering Drawing
Tulane University New Orleans	Engineering Drawing (2 courses) Machine Design
	Maryland
Johns Hopkins University Baltimore	Electricity Applied to Aircraft Industrial Organization and Management Materials Inspection and Testing Mechanical Design for Radio Engineers Plastics Production Fundamentals Radio Engineering Time and Motion Study
University of Maryland College Park	Aeronautical Drafting and Design Aircraft Inspection Aircraft Tool Engineering Radio Engineering Radio Testing and Inspection

	Massachusetts
Massachusetts Institute of Technology, Cambridge	Aeronautical Engineering Aircraft Engines Applications of Metallography Applied Mathematics Defense Production Coordination and Expediting Dynamic Analysis of Servomechanisms Engineering Fundamentals Exterior Ballistics Instrumentation and Vibration Measurement Marine Engineering Naval Architecture Ordnance Inspection Textile Testing Vibrations and Their Applications
Northeastern University Boston	Applied Mechanics Elementary Airplane Structures Engineering Drawing Higher Mathematics Instrumentation Machine Design (2 courses) Materials Inspection and Testing (2 courses) Methods Engineering Production Engineering and Supervision Production Supervision
Tufts College Medford	Applied Mathematics Chemistry in National Defense Concrete Inspection and Construction Engineering Drawing Foreman Conferences and Instructor Training Machine Design Physical Metallurgy Production Engineering Radio Engineering Theory and Practice of Welding
Worcester Polytechnic Institute Worcester	Elements of Machine Design Elements of Tool Engineering Materials Testing and Inspection
	Michigan
Detroit Institute of Technology Detroit	Machine Design Tool and Die Design
Michigan College of Mining and Technology, Houghton	Engineering Drawing Machine Design Materials Inspection and Testing
University of Detroit Detroit	Aeronautical Engineering Drawing, Descriptive Geometry, and Shop Mathematics Materials Inspection and Testing Production Engineering Production Supervision

University of Michigan Ann Arbor	Machine Design Materials Inspection and Testing Production Engineering and Supervision Tool Engineering
Wayne University Detroit	Electronics Engineering I Engineering Drawing I Engineering Drawing II (Descriptive Geom.) Engineering Drawing III (Freehand Drawing) Industrial Organization and Factory Management Machine Design Material Testing Metallurgy Shop Processes, Mathematics and Measurements Telephone Communication
	Minnesota
University of Minnesota Minneapolis	Engineering Drawing Machine Design Metallurgy and Metallography Optical Engineering
	Mississippi
Mississippi State College State College	Engineering Drawing Materials Inspection and Testing Tool Engineering
	Missouri
Washington University St. Louis	Machine Design Material Inspection and Testing Production Engineering Production Supervision Tool Engineering
	Nevada
University of Nevada Reno	Civil Engineering Drawing
	New Hampshire
University of New Hampshire Durham	Engineering Drawing
	New Jersey
Newark College of Engineering Newark	Engineering Drawing Machine Design Materials Inspection and Testing
Rutgers University New Brunswick	Machine Design

Stevens Institute of Technology Hoboken	Elements of Engineering Drawing Introduction to Engineering
	New Mexico
New Mexico College of Agricultural and Mechanical Arts State College	Engineering Drawing Machine Design Materials Inspection and Testing
	New York
Cornell University Ithaca	Advanced Stress Analysis and Elastic Stability Electronics Materials Testing and Physical Metallurgy Mechanics and Elementary Aircraft Design
New York University New York City	Aerial Bombardment Protection Aircraft Stress Analysis Procedure Elements of Advanced Aircraft Engine Design Food Inspection Fundamentals of Aircraft Fitting Design Gaging and Inspection Methods Heat Treatment of Aluminum Alloys Introductory Aerodynamics Marine Engineering Materials Testing with Laboratory Metallurgy and Metallography Military Sanitation Production Control Time and Operation Study
Pratt Institute Brooklyn	Engineering Drafting and Practice Production Engineering
Union College Schenectady	Chemistry of Metals Design of Highly Stressed Structures and Apparatus Drafting and Drafting Room Practice Electron Tubes and Their Applications Elementary Electrical Theory and Practice Elementary Mechanics and Strength of Materials Engineering Materials and Manufacturing Methods Engineering Problems and Their Mathematical Solution Industrial Applications of Optics Industrial Chemistry Internal Combustion Engines Methods Improvement by Motion Study Principles and Practice of Radio Communication Production and Cost Control Tool Design

North Carolina

Agricultural and Technical College of North Carolina Greensboro	Materials Inspection and Testing
Duke University Durham	Communication Engineering Machine Design
North Carolina State College Raleigh	Aircraft Inspection Chemical Testing and Inspection Diesel Engineering Engineering Drawing Experimental Electronics Instrument Men and Topographers Machine Design Materials Inspection and Testing Production Engineering Production Supervision

North Dakota

University of North Dakota University	Engineering Drawing Materials Inspection and Testing

Ohio

Case School of Applied Science Cleveland	Electrical Maintenance and Control Elements of Motion Economy Engineering Surveying Explosives Fundamentals of Machine Design Industrial Instrumentation Inspector and Metallurgical Technician Training Internal Combustion Engine Testing Machine Detailing
University of Cincinnati Cincinnati	Materials Inspection and Testing Production Supervisor
Fenn College Cleveland	Engineering Drawing Material Inspection and Testing Non-Metal Material Testing Production Engineering Production Supervision Stress Analysis Structural Detailing Tool Engineering
Ohio State University Columbus	Air Navigation Communications Laboratory Technique Design of Chemical Plant Machinery and Equipment Engineering Drawing Explosives Inspection of Materials of Chemical Industry (A. S. T. M. methods) and Chemicals Inspection of Construction Materials

Ohio State University —*Continued*	Inspection of Instruments Inspection and Testing of Small Electrical Power Units Inspection and Testing of Small Internal Combustion Engine Power Units Inspection of Steel and Cast Iron Products Inspection of Welded Products Machine Design Physical Metallurgy Production Engineering Production Supervision Tool Engineering Welding Engineering Design
	Oklahoma
Oklahoma Agricultural and Mechanical College, Stillwater	Engineering Drawing Machine Design Materials Inspection and Testing Production Engineering Tool Engineering
University of Oklahoma Norman	Aeronautical Engineering Engineering Drawing (2 courses)
	Oregon
Oregon State College Corvallis	Aeronautical Engineering
	Pennsylvania
Bucknell University Lewisburg	Engineering Drawing Materials Inspection and Testing Production Engineering
Carnegie Institute of Technology Pittsburgh	Cost Control Elementary Industrial Chemistry Elements of Metallurgical Engineering Engineering Drafting Industrial Relations Machine Design Production Engineering Production Supervision Testing and Inspection
Drexel Institute of Technology Philadelphia	Chemical Plant Operation Electrical Circuit Theory, Machines and Instruments Machine Design Marine Electrical Engineering Production and Tool Engineering
Grove City College Grove City	Engineering Drawing
Lehigh University Bethlehem	Instrument Design Machine Design

Pennsylvania State College State College	Diesel Engineering Electronics and Electron Tubes Elementary Engineering Drafting Elementary Machine Design Elementary Tool Design Fuel Technology Operation Inspection Petroleum Refinery Control Physical Metallurgy Physical Testing of Materials (2 courses) Pre-Foremanship Training in Production Supervision Production Engineering (2 courses) Pyrometry Test Calculations and Instrumentation Time and Motion Study
University of Pennsylvania Philadelphia	Chemical Engineering for Production Supervision Diesel Engineering, Design and Construction Machine Design Motion Study—Time Study—Wage Incentives Physical Metallurgy Production Engineering Production Management Production Supervision Safety Engineering
University of Pittsburgh Pittsburgh	Engineering Materials Inspection and Testing Machine Design Machinery Inspection and Testing Mechanical Drawing and Descriptive Geometry Metallurgical Inspection Production Engineering Production Planning
	Rhode Island
Brown University Providence	Elements of Machine Design Engineering Drawing Engineering Mathematics Jig and Fixture Design
	South Carolina
Clemson Agricultural College Clemson	Elementary Drafting
	South Dakota
South Dakota State College Brookings	Machine Design

	Tennessee
Tennessee Polytechnic Institute Cookeville	Engineering Drawing
University of Tennessee Knoxville	Electric Communications Elementary Mathematics for In-Service Training Materials Inspection and Testing
Vanderbilt University Nashville	Engineering Drawing Machine Design Materials Inspection and Testing
	Texas
Agricultural and Mechanical College of Texas College Station	Aeronautical Engineering Aircraft Inspection Camp Sanitation Engineering Drawing Material Inspection and Testing
Southern Methodist University Dallas	Engineering Drawing Production Supervision
Texas College of Arts and Industries, Kingsville	Engineering Drawing
Texas Technological College Lubbock	Production Engineering
University of Texas Austin	Engineering Drawing Materials Inspection and Testing (2 courses) Soil Mechanics Laboratory Technique Structural Drafting
	Utah
University of Utah Salt Lake City	Aeronautical Engineering General Metallurgy Industrial Electronics Machine Design Materials Inspection and Testing Mechanical Drawing and Descriptive Geometry Ore Dressing
	Vermont
Norwich University Northfield	Engineering Drawing
	Virginia
University of Virginia Charlottesville	Engineering Drawing Industrial Electronics Materials Testing and Inspection Production Supervision Principles of Radio Simple Aerodynamics and the Airplane

	Washington
State College of Washington Pullman	Engineering Drawing
University of Washington Seattle	Advanced Mechanics of Structures Aircraft Descriptive Geometry Aluminum and Its Alloys Design and Operation of Radio Equipment Fundamentals of Aerodynamics Fundamentals of Communications Hull Fittings and Mechanical Devices in Warship Construction Junior Marine Engineer Mechanical Engineering (Heat and Ventilation) Mechanics of Structures Metallography Naval Architecture Naval Architecture and Ship Drafting Naval Practice in Electrical Engineering Ordnance Design Ship Piping Design for Mechanical Engineers Technical Sketching
	West Virginia
West Virginia University Morgantown	Drafting and Designing Metallurgy Process Engineering (Chemical) Production Supervisors Testing and Inspection
	Wisconsin
Marquette University Milwaukee	Materials Inspection and Testing Production Engineering
	Wyoming
University of Wyoming Laramie	Engineering Drawing
	Puerto Rico
University of Puerto Rico Mayaguez	Communication Engineering

MACHINE DESIGN AS A MEDIUM FOR TEACHING ENGINEERING FUNDAMENTALS

By H. A. BOLZ

Assistant Professor of Mechanical Engineering, Purdue University

The course of study in machine design, ordinarily offered to undergraduate technical students, may be so constituted as to present an ideal means of teaching the general fundamentals of engineering. It is unexcelled in this respect by any of the other courses included in the usual mechanical-engineering curriculum of today and is equalled by only a few of the non-elective subjects taught in the other branches of engineering instruction. A careful analysis of the content and conduct of the course in machine design will demonstrate its possibilities in this respect and may serve an additional purpose in helping young instructors to begin the formulation of a sound philosophy of teaching.

This analysis will disclose the fact that the art of designing machines and machine members involves the application of mathematics, the laws of science, the principles of economics, considerable analytic ability and a generous amount of common sense in a definite procedure known as "the scientific method."

This is engineering itself, for engineering has been defined, in essence, as the art of applying the laws of mathematics and the sciences to the economical adaptation and control of the forces and resources of nature for the benefit of society. Consequently, the fundamentals of machine design, properly taught, need not be limited in application to their field alone but should equip the student to attack engineering problems in any field.

In the light of the foregoing reasoning, the design instructor has the opportunity of contributing immeasurably to the development of engineers. Whether he takes advantage of this opportunity or not is his to decide. In either case, he should be able to offer a creditable training in machine design, but it is only by a particularly careful presentation of his material that he will be able to make this training of a truly fundamental engineering nature.

In regard to the application of mathematics in machine-design procedure, the derivations of the commonly-used design formulas are rich with interesting examples. Such derivations often give new and vital significance to the principles of geometry, algebra

and calculus that otherwise seemed uninteresting to the student. By emphasizing the mathematical treatment of his subject, the design instructor may very well change the common feeling of aversion toward mathematics to one of appreciation and respect.

The principles of mechanics, likewise, may be returned to the student's attention in a light that gives them a practicable and consequently interesting meaning. Static and dynamic analyses of actual machine members may be particularly effective in this direction when performed as part of a long design project involving a complete machine. The laws of motion are reviewed thereby in detail and their effects impressed in a more lasting manner upon the mind of the student.

Besides mechanics, it is easily possible to introduce many other principles of physics into the process of design. For instance, the use of the thermal expansion and contraction of materials in the assembly of parts and the study of stresses resulting from restrained thermal expansion constitute interesting applications. Electrical phenomena are demonstrated in the use of such devices as solenoids and resistance welders. Even chemistry may be brought into use occasionally in the consideration of the behavior of materials subjected to corrosive elements; while the atomic and crystalline structure of metals shows evidence of a decidedly live and practical significance in the study of, for example, fatigue characteristics.

As to economics, it would be difficult to find a more interesting or expedient subject than machine design by means of which to stress some of the principles governing and effects resulting from our problems of production and distribution. This may be attributed to the fact that, to be designed properly, a machine not only must perform the functions required of it but must perform them at a minimum overall cost. For instance, the design student learns that, although a shaft of 3.73 inches diameter may be sufficiently large for a given installation as far as strength and stiffness are concerned, he will find it more economical to use one of a larger diameter, namely, three and fifteen-sixteenths inches. This is a result of two conditions. First, the latter size may be purchased from open stock at a lower cost than the former size, which would require special machining; and second, the bearings and fittings that would be required are more easily procured in the latter size, which is a trade standard. Machine design procedure is replete with economical considerations of a similar nature. Such considerations usually require an exercise of common sense and mature judgment, the seeds of which may be planted by the instructor to develop in the sunlight of further experience. The mention of trade standards brings to mind another phase of the economic side of engineering that is exemplified in the study of design. While

the design student should be encouraged to apply originality to his work and to base his designs upon the elements of physical science and mathematics rather than upon handbook formulas, he also should be shown that, for the sake of standardization and safety, his results must satisfy certain accepted engineering codes. Such standards as the A. S. M. E. Transmission Shafting Code, the A. G. M. A. gear design recommendations and the A. S. M. E. Boiler Code are examples of some of the trade standards which serve to acquaint the machine design student with many of the practical features of engineering.

Economic effects may be reflected also in the form of such factors as the current trend toward aesthetic styling. The influence of this trend is so broad as to necessitate an appreciation of its principles by everyone connected with production, distribution and construction. The study of machine design offers a timely means of introducing the student to the fundamentals of designing for appearance's sake and should serve to stimulate in him that aesthetic sense which, ordinarily, is a rare characteristic in engineers in spite of its growing influence upon the results of their work.

In regard to the scientific method itself, machine design offers some exceptionally suitable illustrations of its uses and benefits. The typical design problem is presented to the student in the form of a written statement requiring a correlation and evaluation of data, a statement of the object of the problem, a recognition of the physical laws governing its solution and, finally, a consequent determination of a solution modified to meet the requirements of production economy. A problem solved in this manner, obviously, has been approached by way of the scientific method. It must be granted, of course, that other courses of engineering study, also, may be taught in such a way as to demonstrate this method of attack. Machine design, however, as mentioned above, is exceptionally effective in this respect, because it involves one additional feature. Its problems may be of such a degree of complication as to constitute rather difficult exercises in analytical reasoning. The process of solving problems of this nature demonstrates the potency of a sound analytical method of approach; that is to say, a method whereby a complicated system of parts is resolved into a series of elementary components, each of which may be attacked as one simple problem.

Once he has learned this principle of analysis, the engineering student will be well over the highest hurdle to be crossed in his path to success. His chief stock-in-trade after graduation should consist of a confidence in the fact that problems seldom are truly complicated but are only complicated arrangements of simple parts, which, when isolated by cool reasoning, will be found subject to the

basic fundamental physical relationships. However, it must be borne in mind, too, that the engineer is often required to serve as a synthesist as well as an analyst; he must be able to build as well as to take apart. This ability to create lies dormant in the majority of our students, because it is stifled by the fear of violating convention. In the design laboratory it is possible to provide problems that not only allow creative freedom but actually demand the application of a reasonable amount of inventive capacity.

By way of summary, it has been shown that machine design instruction, properly administered, furnishes sound training in the basic fundamentals of engineering. It supplies practice in the application of mathematics, promotes a familiarity with the principles of physics and chemistry and demonstrates the influences of economic practices. It teaches the scientific method, encourages the use of common sense, starts the development of mature judgment and stimulates creative ability.

These aspects of the study of machine design are not set forth here as newly-discovered principles. They are as old as the subject itself but are deemed worthy of emphasis now because they may drift from sight very readily before the rising wave of complications and specialties introduced by our rapidly advancing technology. The machine-design instructor is indeed fortunate in having at his disposal such expedential devices for teaching and illustrating the fundamental tenets of engineering practice.

HEAT TRANSFER INSTRUCTION IN AGRICULTURAL ENGINEERING*

By F. A. BROOKS and R. L. PERRY,

Associate Professors of Agricultural Engineering, University of California

Introduction

Heat transfer is one of the primary factors in agriculture. All of the biological processes depend ultimately on solar energy or its equivalent, and heat exchange between living cells and their environment is essential to life. Warm blooded animals including humans must dispose of thermal energy continually or life ceases, and plants cannot live without circulation due to evaporation which in turn depends upon heat transfer.

Heat exchange is an outstanding variable in our environment. The weather is the grand example. The diurnal cycle of the hot day and frosty night, and the seasons are manifestations of periodic heat flow which are inescapable.

On the surface of the earth, agricultural operations carried out by mechanical equipment are usually timed in relation to heat flow. The increasing warmth of spring as the seasonal temperature curve rises from the winter minimum is first associated with wet ground, and the seemingly prosaic field operation of plowing cannot be carried out until by the transfer of latent heat of evaporation the soil is dried sufficiently to be workable. Harvest time is not haphazard, but follows blossoming according to a characteristic number of degree days based on a physiological zero temperature.

In the practice of agricultural engineering, direct use is made of heat transfer in the processing and storage of agricultural products, particularly in dehydration, refrigeration, pasteurization, cooling, canning, etc.

So in general we look upon heat transfer as a predominant factor in which students of agricultural engineering should be thoroughly grounded. Heat transfer is of course a major field of activity of all engineers, and the foregoing introduction is simply to point out why the rigorous instruction of the subject for mechanical engineers is given also to agricultural engineering students.

* Presented at the 48th Annual Meeting, S. P. E. E., University of California, June 24–28, 1940 (Mechanical Engineering).

Agricultural Engineering Students are Trained Primarily as Engineers

Agriculture is an extremely complex biological industry, and in California is highly specialized. Furthermore, the various biological problems are attacked by highly trained specialists who with some justification regard engineering problems as essentially simple—not being involved with irreversible life processes which can be treated analytically only on statistical bases. The field production problems are usually presented by growers' organizations and engineering phases again are incidental, although often vital. As the industry advances it becomes necessary to supersede rule-of-thumb practice by adequate engineering. These factors normally place the agricultural engineer in a service capacity. His function is to solve the engineering problems of agriculture. As agricultural products come more into industrial non-food uses, engineering will be more important. The graduate in agricultural engineering must accordingly be primarily an engineer, although incidentally he may mature into an agriculturalist.

The agricultural engineering students in the University of California pursue the regular mechanical engineering curriculum with no substantial specialization until their senior year when residence is at the Branch of the College of Agriculture at Davis. Then their studies of agricultural operations and equipment are treated as extensions of their previous analytical training. Of course, some of the students find it difficult to grasp the heat and power relations in what to the uninitiated appear to be crude haphazard operations, but a theoretical attack on such common agricultural heat transfer problems as curing of hay, natural draft barn ventilation, "sweating" on wall and roof surfaces, quickly reveals the need for analytical treatment. Most agricultural processes involve periodic exposure and important transient environmental conditions which make the solution of heat transfer problems in agriculture more complicated than most of those in heat-power.

Courses of Instruction in Heat Transfer

Students electing the agricultural engineering option have preliminary instruction in heat in three required courses. Physics 1B includes the fundamental treatment of heat. Mechanical Engineering 105A–B (Thermodynamics) gives the conventional treatment of heat transmission, and Mechanical Engineering 10A–B gives some conception of strong transient heat flow in connection with heat treatment of metals.

In view of the previous instruction, the senior agricultural engineering students first receive advanced instruction on heat trans-

fer in Mechanical Engineering 151, Industrial Heat Transfer. This course covers the following:

A. Elementary treatment of conduction, convection and radiation
B. Steady state conduction
C. Transient conduction
D. Periodic conduction
E. Internal heat sources
F. Free convection
G. Forced convection, normal to tubes
H. Forced convection in tubes
I. Heat exchangers
J. Radiation
K. Errors of temperature measurement

The lecture topic schedule is given in Appendix I.

There is no substantial difference between this course as given at Berkeley and at Davis, except that the illustrations and problems are taken from mechanical engineering in one, and from agriculture in the other. As text, selections are made from "Heat Transfer, Supplementary Notes for Mechanical Engineering Course 267A–B," Boelter, Cherry and Johnson.* The students also use "Heat Transmission," McAdams, for standard applications of forced convection and radiation. "Industrial Heat Transfer," Schack, Goldschmidt and Partridge, is referred to occasionally.

In the second semester the students in agricultural engineering receive instruction in heat and mass transfer in Mechanical Engineering 152, Thermodynamics of Industrial Equipment. This course covers the same topics at Davis as at Berkeley, but again, at Davis the examples and problems are largely taken from agriculture. For agricultural engineering students, more time is devoted to evaporation, drying, and cooling problems in air conditioning which relate to cold storage, and consequently less time is available for stripping and distillation. The subject outline is as follows:

A. Evaporation
B. Boiling and condensation
C. Adsorption, absorption and stripping
D. Distillation
E. Psychrometry
F. Cooling towers
G. Drying
H. Filtering
I. Air conditioning
J. Combustion

* University of California Press, Berkeley, California.

The outline by periods is somewhat flexible, but the one given in Appendix II is typical.

Because there is not time enough to treat all subjects completely, it is necessary both in Berkeley and in Davis to make some selection which is naturally pointed toward the anticipated field of activity of the student. For the agricultural engineering students more emphasis is placed on the involved problems of heat transfer outdoors to insure a clear conception of the interaction of solar radiation, the atmosphere, foliage, ground, and moisture. (Fig. 1.) For

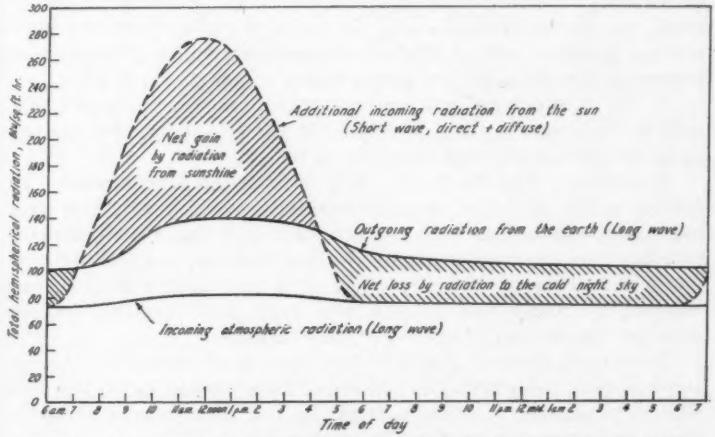
Additional incoming radiation from the sun
(Short wave, direct + diffuse)
Net gain by radiation from sunshine
Outgoing radiation from the earth (Long wave)
Net loss by radiation to the cold night sky
Incoming atmospheric radiation (Long wave)
Time of day

FIG. 1. Diurnal radiant energy exchange between the sky and ground at Riverside, California. Feb. 23–25, 1939.

instance the student learns how a nocturnal radiation frost can occur in July in quiet, dry low spots in the hot Sacramento Valley. He also finds that, with spectral differences in radiation—short wave solar energy vs. long wave thermal radiation—glass greenhouses are effective because of change of transparency of glass with wave length, and white surfaces have cooling power because of the change of emissivity with wave length.

The extra attention to outdoor heat transfer requires some reduction of time given to more classical topics such as alternative derivations of mathematical relations, and theoretical aspects of hydrodynamics. Dimensionless criteria are employed throughout although dimensional analysis is accorded only brief treatment. The variation of thermal conductivity with moisture content of soils is considered an adequate and important substitute for the usual treatment of variation with temperature.

Course Examples in Mechanical Engineering 151 at Davis

Considerable difference will be found in the examples given at Davis compared with those at Berkeley. This change of examples does not alter the course but serves to acquaint the student with heat transfer problems typical of the agricultural industry which for the moment at least is his chosen field.

The problems selected are cited here as fair examples of heat transfer in agricultural engineering. The material is taken largely from our research projects and therefore has the double advantage of covering current problems and of being the result of intensive study by the instruction staff. In cases where agricultural engineering practice does not afford adequate examples of analytical treatment, better industrial examples are of course supplied.

A list of problems and examples pertaining to the topics covered in the course is given in Appendix I–A. Among these are the more specific agricultural examples as follows:

Conduction Transients.—Cooling of fruits and vegetables. In cooling solids of finite thermal conductivity, such as fruits and vegetables, the surface temperature leads and the center temperature lags the exponential curve idealized for solids of infinite conductivity. This conductivity effect, and that of the heat energy released by respiration explain why fruit and vegetable cooling does not follow simplified laws of heat transfer.[1, 2]

Sterilizing Canned Goods.[3]—Idealization of conditions encountered in heat penetration and removal from canned goods has permitted prediction of results from limited data, where formerly many repetitive observations were required.

Pipe-line Insulation for Intermittent Use.—Graphical solution of transient heat flow in hollow cylinders facilitated analysis of pipeline insulation economy. For short-time daily use, present commercial recommendations were found excessively thick.

Conduction, Periodic.—Heat flow through roofs. The effect of solar energy gives a roof surface temperature which is essentially a fundamental and second harmonic.[4, 5]* (Fig. 2.) Heat capacity of insulating material is of less significance than anticipated where it is small in proportion to the heat capacity of the roof structure itself.

*Heat Flow Into and Out of the Ground.** (Fig. 3.)—This is complicated by the change in thermal diffusivity with depth, due to moisture gradient, variations in surface cover, and change in moisture content with time.

Internal Heat Sources.—Quick freezing of fruits, vegetables

[1, 2] Superior figures refer to terminal bibliography.

* Illustrated with lantern slides.

and juices. Because of the low concentration of dissolved solids, most of the latent heat is removed at a substantially constant temperature.* (Fig. 4.) However, the thermal conductivity of the frozen material is greater than that yet unfrozen, and the process is further complicated by rather haphazard subcooling.[6, 7] * (Fig. 5.)

Electric Soil Heating.—The gradient changes rapidly near the heating cables. Wire spacing, depth and load must be arranged to avoid local hot and cold spots.[8]

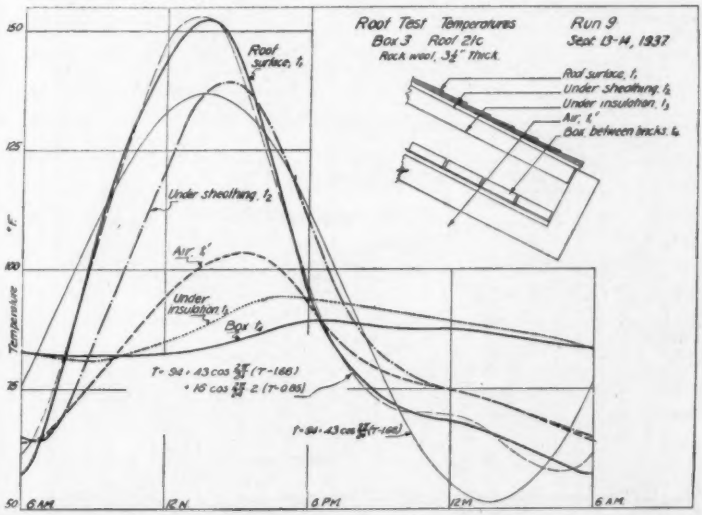

FIG. 2. Roof test temperatures with rock-wool insulation 3½ inches thick. Davis, Calif. Sept. 13–14, 1937.

Thermo-syphon Circulation.—Solar water heater circuit of absorber and storage tank. The rate of circulation and temperature rise are interdependent but in opposition, and both are influenced by the relative level of the absorber which must be below the tank to prevent reverse circulation at night.[9] There is also the problem of connecting an auxiliary side-arm heater so that neither absorber will afford heat dissipation for the other.

Stable Ventilation.—Natural ventilation of stables in winter dependent upon animal heat output must be restricted to maintain satisfactory temperatures.[10] This is particularly important in poorly insulated structures in cold climates because of the added problem of condensation.

Convection, Forced.—Coil pasteurizers. In the region of low Reynold's numbers which obtain with low coil speeds, handling viscous products at low temperatures, heat transfer may occur in

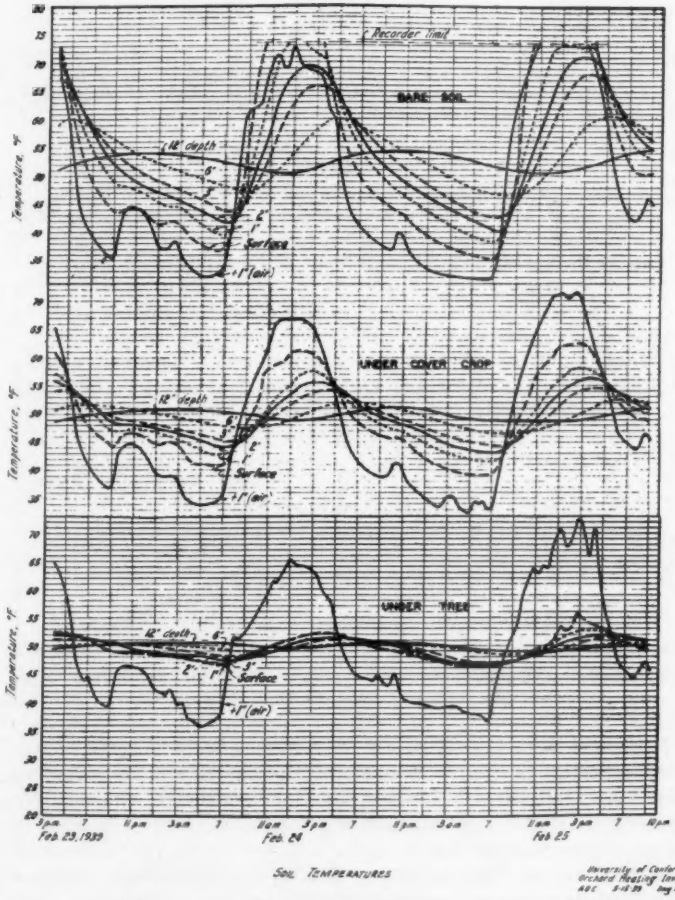

FIG. 3. Soil temperatures under bare surface, under cover crop and under orange tree at Riverside, Calif. Feb. 23–25, 1939.

the transition zone between free and forced convection, making analysis uncertain.[11] This presents a serious problem to the designer because all of the milk must be brought to the required

pasteurizing temperature and held there for the required time which will insure destruction of all pathogenic organisms, yet there must be no hot spots which will produce a detectable cooked flavor.

Plate Heat Exchangers for Dairy Products.—With equipment which has been designed to give high unit rates of heat transfer, departures from design conditions may produce material changes in performance.

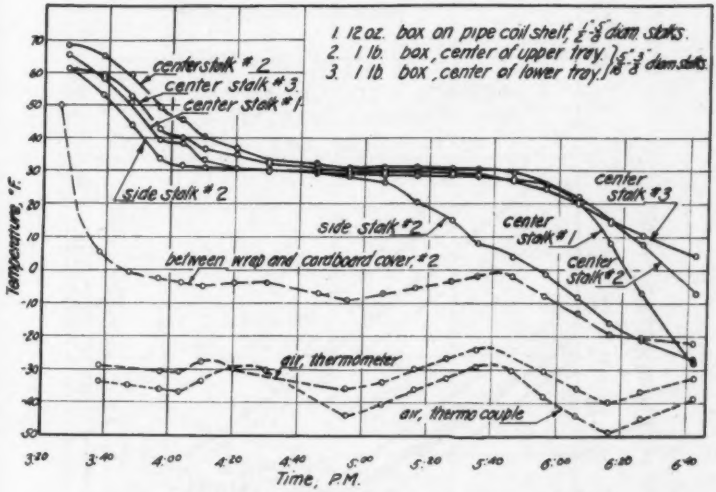

FIG. 4. Freezing asparagus in the package in an air blast.

Radiation.—Orchard heating.[12, 13] Radiation from orchard heaters includes the involved concept of the shape factor of the orchard, and also interpretation of heater radiation distribution, which shows that intensity nearly horizontal is much more important than vertical because of the large horizontal belt in contrast to a small zenith cone of the same angle.* (Fig. 6.) Nocturnal radiation cooling is shown as the difference between the highly selective incoming atmospheric radiation and the nearly black body out-going radiation from foliage. Examples in radiation from gases are taken from atmospheric observations which show a 20 per cent absorption of black body thermal radiation in 20 feet when the dew point is 45° F.

EXAMPLES FROM MECHANICAL ENGINEERING 152

Evaporation.—Evaporation from open water surfaces by free convection. In introducing this, the concept is presented of free

or natural convection, with the driving force being the difference in density caused by differences in concentration and temperature.[14] The mass and energy balance method is also used.

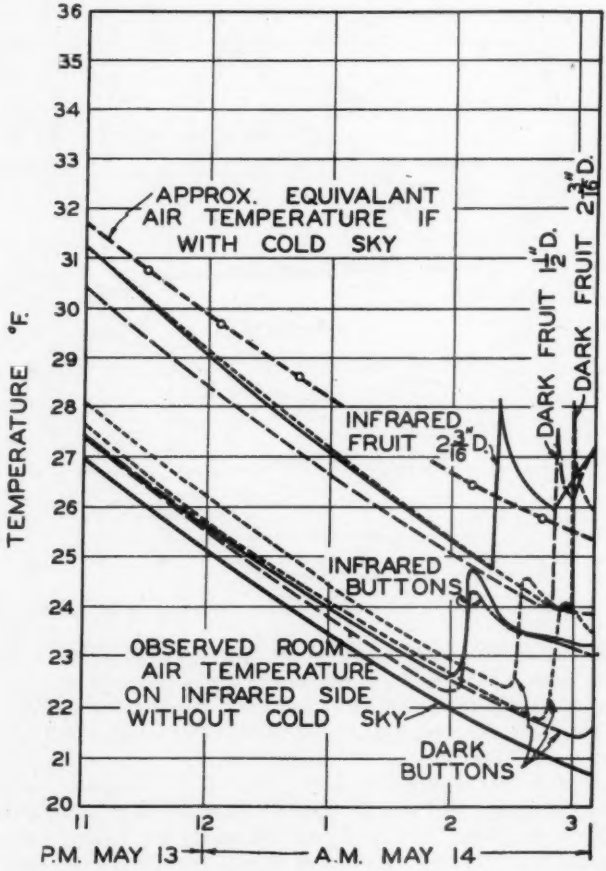

FIG. 5. Freezing of lemon tree fruit under infrared illumination and in the dark.

Adsorption.—Moisture content of agricultural commodities.[15, 16] Grains, wool and cotton harvested in dry climates gain appreciably in weight when stored under more humid conditions preliminary to ocean shipment. The milling quality of rice is reduced by low

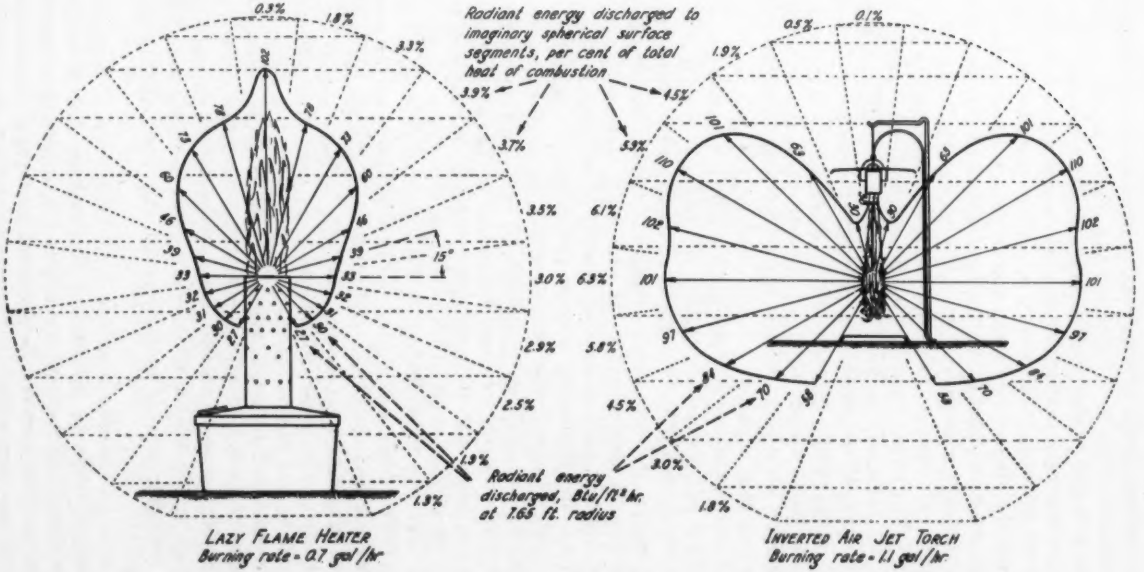

FIG. 6. Intensity distribution of radiant energy discharged by lazy-flame and by air-jet orchard heaters.

moisture content resulting from harvesting and storage under low humidities.

Cooling Towers.—Mass and energy transfer resulting from differences in concentration and temperature are verified with mass and energy balances.[17] However, in agriculture, the common application is the atmospheric tower where the air movement through the tower is not accurately known, and where the air final conditions are difficult to determine.

Drying.—The conventional approach of resistance to internal diffusion, and surface resistance to mass transfer is used. Many agricultural commodities must be handled carefully to prevent case-hardening. The student learns that the relatively constant wet bulb temperature throughout the drier which facilitates calculations is the fortunate result of the numerical similarity of the heat transfer coefficient,—water vapor diffusion coefficient ratio and the unit heat capacity.

Air Conditioning.—Comfort cooling. The evaporative cooler has found a widespread acceptance for home cooling in the dry climates of the southwestern states. In this unit, cooling air by the evaporation of water, the increase in humidity is so related to the drop in temperature that the wet bulb temperature of the cooled air is the same as that of the air supplied. It has been argued that this should not give more comfortable conditions because the rate of energy loss by convection and evaporation from a wet surface is the same for conditions of equal wet bulb temperature. Apparently the substantial increase in radiation losses resulting from lower wall temperatures is largely responsible for the increased comfort secured with the evaporative cooler.

Fruit and Vegetable Storage.—With storage of fruits, vegetables and frozen foods, more attention is being given to the prevention of wilting and shrinkage, and to the atmospheric composition which will give maximum storage life.[18, 19]

Combustion.—In orchard heaters of the bowl type the energy for vaporizing the fuel is obtained both from a pilot flame in the bowl and radiation from the main combustion in the stack. The pilot flame is necessary for stability, but is objectionable as a source of soot formation in the bowl. Dilution of the oil vapor-air mixture in the bowl with inert stack gas has been found effective in reducing soot accumulations in the bowl and in smoke prevention.[20]

As an alternate to Mechanical Engineering 151 there is at Davis an upper division course, Physics 116, in the Department of Agriculture. This includes fundamental concepts of thermal properties of matter, mathematical theory of conduction, radiation laws,

and kinetic theory of gases. Occasionally Chemistry 110, Physical Chemistry, also offered in the Department of Agriculture at Davis, may be substituted for Mechanical Engineering 152 as a restricted elective of equivalent worth although the course contents and treatment are different.

A few periods of heat-transfer instruction are also given in the second semester senior year at Davis in the proseminar course, Agricultural Engineering 130. These are mainly to test the stu-

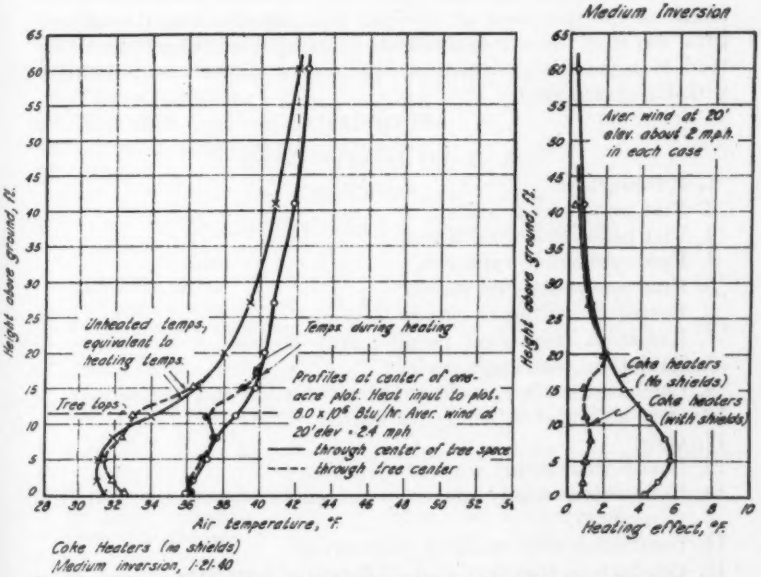
Medium Inversion
Height above ground, ft.
Air temperature, °F.
Unheated temps., equivalent to heating temps.
Temps. during heating
Tree tops
Profiles at center of one-acre plot. Heat input to plot. 8.0 x 10⁶ Btu/hr. Aver. wind at 20' elev. = 2.4 mph
through center of tree space
through tree center
Coke Heaters (no shields)
Medium inversion, 1:21:40
Aver. wind at 20' elev. about 2 m.p.h. in each case
Coke heaters (No shields)
Coke heaters (with shields)
Heating effect, °F.

FIG. 7. Heating effect in a 1-acre orange grove by shielded and unshielded coke heaters.

dents' grasp of fundamental physical laws such as are involved in the zenith to horizon variation of apparent temperature of the night sky due to atmospheric radiation, and density currents of air chilled by nocturnal radiation of foliage. (Fig. 7.)

CONCLUSION

In general, the agricultural engineering graduate must be prepared to undertake heat transfer studies usually involving many variables and rarely of steady state nature. In several branches of agriculture processing, heat transfer is well understood, as for instance in the canning industry. Adequate concepts of dehydra-

tion factors are now being formed—the "case-hardening" of fruits has been difficult to avoid. The cold-storage problems are now highly special. This state of the industry is reflected in the selected bibliography of agricultural heat transfer papers listed in Appendix III.

In conclusion, we might simply say that the agricultural engineering student is faced with important and difficult heat-transfer problems and our instruction covers the same subject matter as taught the mechanical engineers. There is some difference in emphasis in the treatment of out-door heat transfer, but the agricultural flavor of the course problems is unimportant except that they tend to make the agricultural engineering student more familiar with his chosen field.

APPENDIX I

M. E. 151 Lecture Topics

1. Introduction.
2. Flat plate, steady state.
3. Flat plate, of several layers.
4. Free convection, cylinders.
5. Free convection, flat plates.
6. Forced convection in pipes.
7. Radiation from solid parallel gray bodies.
8. Radiation, with angle factor.
9. Combined surface coefficients for radiation and convection.
10. Over-all transfer factors for walls.
11. Quiz.
12. Conduction, steady state in cylinders.
13. Conduction steady state, in irregular objects by graphical methods.
14. Conduction with variable conductivity.
15. Conduction, transient state, differential equations.
16. Conduction, transient state, integrated equations for typical different initial and boundary conditions.
17. Conduction, transient state, graphical solutions.
18. Conduction, transient state, cooling of fruits and vegetables.
19. Conduction, transient state, insulation problems.
20. Conduction, with periodic temperatures. Fourier series.
21. Temperature pattern and heat flow, with semi-infinite solid.
22. Finite solids with periodic surface temperatures.
23. Heat flow through building structures.
24. Heat flow in and out of ground.
25. Internal heat sources, freezing.
26. Soil heating with electricity.
27. Free convection, Grashof's and Nusselt's numbers.
28. Convection by wires, pipes in air and liquids.

29. Quiz.
30. Thermosyphon circulation, buoyant forces and resistance.
31. Convection, forced, in pipes, with streamline and turbulent flow.
32. Convection in tubes, effect of entrance conditions, distortion from isothermal flow pattern.
33. Convection, forced, across tubes.
34. Simplified and empirical convection equations.
35. Heat exchangers, steady state, parallel and counterflow.
36. Batch heat exchangers.
37. Radiation, from solid bodies, selective.
38. Gaseous radiation.
39. Flame radiation.
40. Sky, earth and tree radiation.
41. Errors in temperature measurement.
42. Quiz.

APPENDIX I–A

M. E. 151 Example and Problem Sources

Topic	*Example and problem sources*
1. Simple flat plate.	Insulation of refrigerator wall.
2. Flat plate of several layers.	Insulation of building walls.
3. Free convection, cylinders.	Bare steam pipe, and surface of pipe insulation.
4. Free convection, flat plate.	Building wall surface and studded space.
5. Forced convection in pipes.	Inside resistance of surface cooler, pasteurizer coil.
6. Radiation, solid parallel gray body.	Studded wall space, with and without foil.
7. Radiation, surrounded objects.	Steam pipes, building walls.
8. Combined coefficients.	Steam pipes, building walls.
9. Over-all coefficients.	Refrigerator, building walls, steam pipes.
10. Conduction, steady state, cylinder.	Pipe insulation.
11. Conduction, steady state, irregular shapes.	In earth by refrigerated basement.
12. Conduction, transient.	Cooling fruits.
13. Conduction, periodic.	Flow through roofs and walls. Earth.
14. Internal sources.	Freezing produce. Soil heating.
15. Free convection.	Electric immersion heater. Furnace pipes.
16. Thermosyphon circulation.	Solar absorber circuit. Refrigerator bunker coil.
17. Convection across tubes.	Fin coil heaters and coolers, pasteurizer coils. Surface coolers (aerators).
18. Heat exchangers.	Pasteurizers, milk coolers, plate heaters.
19. Radiation.	Earth, tree and sky in frost protection.
20. Thermometer errors.	Effect of heat capacity, conduction along leads, radiation in gases.

APPENDIX II

M. E. 152 Lecture Topics

1. Review of heat transfer.
2. Driving forces: temperature, voltage, vapor pressure, concentration differences.
3. Evaporation from a quiet surface.
4. Free convection analogy for evaporation.
5. Energy balance method for free evaporation.
6. Forced evaporation, with heat transfer analogy.
7. Boiling, mechanism of vapor bubble formation.
8. Boiling, energy rates, dimensionless criteria.
9. Duhring's, Trouton's rules. Henry's and Raoult's laws.
10. Clausius-Clapeyron equation.
11. Multiple effect evaporators.
12. Condensation—drop and film wire, resistances.
13. Diffusion.
14. Adsorption, equilibrium, rates.
15. Decolorizing, drying, deodorizing.
16. Absorption, sulfuric acid-water vapor system.
17. Absorption towers.
18. Quiz.
19. Stripping.
20. Application of absorption equations.
21. Distillation, petroleum.
22. Distillation of temperature sensitive substances.
23. Psychrometry.
24. Water vapor-air mixture thermal properties.
25. Cooling towers.
26. Drop analysis.
27. Cooling towers as columns.
28. Drying—temperatures and vapor pressure differences.
29. Drying—moisture diffusion, gradients.
30. Drying—forage crops.
31. Drying—fruits and vegetables.
32. Spray and roll drying.
33. Quiz.
34. Filter types.
35. Resistances and capacities for various precipitates, dust filters.
36. Air conditioning—human response.
37. Humidifying and dehumidifying.
38. Heating and cooling.
39. Combustion—solid, liquid and gas fuels.
40. Furnaces.
41. Orchard heaters.
42. Quiz.

APPENDIX III

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AN INDUSTRIAL VIEW OF COLLEGE AND POST COLLEGE ENGINEERING EDUCATION *

By R. C. MUIR

General Electric Company

To expect the four-year college technical graduate to be a finished engineer, a business man, an executive, a contractor, a lawyer, a patent attorney, a philosopher, a financier, an expert in human relations, a cultured gentleman with some artistic ability and fine appreciation of the arts, is just expecting too much, and still I presume that every dean of an engineering school has had intimations that his graduates fall short of these over-all qualifications, and something should be done about it.

These criticisms have been taken seriously by the engineering educators, and I presume that is why we have the Society for the Promotion of Engineering Education. The educators have also taken a prominent part in the Engineers' Council for Professional Development, and probably for this reason the efforts of this council have been directed largely towards improving the engineering school.

As a result of this individual and collective effort the technical schools have benefited greatly and will continue to benefit, but a better over-all result might be produced if a relatively larger amount of the Council's effort were placed upon post college development of the graduate engineer.

Let us first consider college education:

How much can we crowd into these four years of undergraduate study?

Has the student reached a degree of maturity where he is ready to assimilate and understand many of the broader aspects of business, economics, and human relations?

Can we accelerate the maturity of the student in judgment, common sense and conservatism without permanently sacrificing the development of those priceless qualifications—imagination, ingenuity, resourcefulness, and courage, which are already present at the student age? Stimulation rather than repression may be paramount during this period of development.

* Presented at the 48th Annual Meeting, S. P. E. E., University of California, June 24–28, 1940 (Joint Conference of Engineering Economy and Mechanical Engineering).

Are there not inherent limitations in any school from the point of view of practical problems which make it impossible to carry the education or training of the individual beyond a certain point?

Should not the four-year undergraduate course be merely a sound foundation upon which the student can, through his continued efforts for self-improvement and experience, develop in a normal or natural way a maturity in judgment and understanding, and a proper sense of direction?

These and many other questions cause me to suggest that we approach this problem by making a plot of the receptivity of the individual at various ages and from this come to some decision as to what knowledge can be most readily assimilated by the student between 16 and 22 years of age, and what he could more readily assimilate later.

We may assume that the accepted curricula of the technical schools which have been developed through long trial and study represent quite well the kind of knowledge which the student can best assimilate at this period of life.

My thought is that in our efforts to meet these numerous criticisms and suggestions we should not allow the introduction of further non-engineering subjects, which the student is not yet ready for, to crowd out or handicap these essential to engineering —mathematics, physical sciences, mechanics and hydraulics, and the purely engineering subjects. It is probable that those non-engineering subjects now contained in the curriculum, as well as the engineering subjects, can be made more useful through more effective pedagogical methods, and I am delighted that more attention is being given to this phase of education.

One of the greatest contributions of the engineer is a greater mastery of time. That is basic. Have we made as much progress in the methods or efficiency of our teaching as we have in production efficiency, communication efficiency, or transportation efficiency? We may be turning out efficiency experts but have a lack of efficiency in our methods of doing it. Our teachers may be like the shoemaker's children. I have heard it said that a certain section of the country produces more labor-saving machinery than the rest of the whole world, but uses less of it. An analysis of the art of pedagogy in our technical schools with a view of doing better what we are now doing, and in less time, may be fruitful.

There are a few principles which appeal to me as most useful in forming engineering school curricula. While these are broadly being followed in most engineering schools, as indicated by Professor D. C. Jackson's recent comprehensive report, these deserve emphasis in my opinion.

The first principle is to teach only subjects the student is prepared for, and which he can make use of personally in the approximate future. After all, one learns only by doing, so that there is no more use in teaching procedures which the student cannot use than there is in attempting to teach swimming to students having no access to water.

The second principle is to adhere to the fundamental teaching of mathematics, physics, and the physical sciences for the main body of the curricula, since these are basic to all engineering.

The third is to continue the development of ability to write and speak English throughout the four-year course, but to do this chiefly through the student's recitations and reports on other subjects rather than by separate English courses beyond the first year.

Finally, it seems to me important to give students some understanding of the nature of business by a brief senior year course, so the student may leave school with the business point of view fresh in his mind.

I question, however, whether a suitable business course for undergraduate engineers has ever been devised. I visualize academic courses in economics, commercial law, contracts and specifications, business accounting and the like, all of which may be quite burdensome to the student as to time and interest, for the reason that the material is so far removed from any specific use he will make of it. On the other hand, I believe a very interesting and useful course in business could be devised which any of the fourth year students could quickly grasp and maintain.

For example, we could first command his interest in such a course through one lecture and recitation period on the mission of the engineer in our present civilization. Probably he has not thought it out broadly, that through engineering we have economic progress, a continued improvement in the standard of living, which means more material things for the average wage or for the day's work, improved facilities for transportation and communication and the leisure time to take advantage of these facilities for travel, social intercourse, or to use it otherwise for the greater satisfaction or enjoyment in life.

Through this first lecture he should understand and feel that economics and business are fundamental to the success of engineering, and he should know something about them. But we should bear in mind we are not trying to make him a cost accountant, or economist, or a financier—all we wish him to know now is that to run a business capital is required, and if the business is successful a suitable return or profit must be made on this capital.

Further that his capital in a manufacturing business consists of:

1. Plant and Equipment,
2. Inventory (raw materials, work in progress, finished stock),
3. Consignments,
4. Receivables (total amount due from customers for sales),
5. Cash (to meet payrools and payment for materials).

He should also know something of costs. Manufacturing cost is made up of:

1. Material (including waste and spoilage),
2. Labor,
3. Overhead (engineering expense including engineering tools, manufacturing supervision, clerical expense in manufacturing operations, depreciation of plant and equipment, light, heat, power, other expense—maintenance, etc.).

To this must be added sales expense and administrative expense to obtain gross costs. Profits represent the difference between sales price and gross costs.

One or two more recitations should be sufficient to cover the importance of control of inventories, high turnover of capital, expense control, the importance of low costs, and how costs may be influenced through ingenuity and design, production planning, machines and manufacturing processes.

Now I believe such a course could be laid out using the practical example of a small manufacturing business and another of a small contracting business, in story form if you will, so that any fourth year man could do a creditable job on it in six recitations and he would remember it. On the other hand, he could spend more time than this on the subject of depreciation alone, one item of cost, and then he might not thoroughly understand it. He could spend all of his four years on the broad subject of economics, finance or accounting, and when he graduated he would be just about as good an economist, financier, or accountant as the graduating student of a technical school is an engineer.

If there is more time available, then I would recommend the course be extended to bring home to the student the importance of cost reduction. Examples of improvement in quality and cost of products or structures through the use of new knowledge, new materials, simplification of design, and especially ingenuity, would make a fascinating subject and would tend to develop the resourcefulness and ingenuity of the student.

My suggestion is that we have engineers adapt these non-engineering or general academic courses included in the engineering

curriculum for maximum engineering utility, rather than accept them as prepared by non-engineering teachers.

There seems to be general agreement upon the desirability of developing in the student in so far as possible those general qualifications so essential to success—character, power of self-expression, poise, personality, alertness of mind and industry. Much of this comes through example and campus activities, and not through credit courses. This phase of education can undoubtedly be improved upon through greater attention to the individual student throughout the four years, and through a more careful choice or training of faculty members. Nearly every graduate has benefited from the guidance or example or remark of some of his professors.

One professor advised his senior students to buy evening clothes with the first money they could save, and another advised his students that it would be wrong to save too much the first year. Both had in mind the social development of the student.

Another told his students he would look them up twenty-five years after graduation to determine whether or not they had been successful. Good advice to the young man who expected to get ahead quickly without further effort. As Edison said, success for most of us must come through perspiration rather than inspiration.

One dean kept reminding the students in a land grant college that they were working for the state—it was costing the state $453.00 per student per year and each student should consider it his obligation to earn it.

And so we might cite many examples of remarks, incidents, or actions of professors which helped to develop the general qualifications of the student.

I am not in the least critical of the technical schools or the progress made. The opening paragraph clearly indicates my sympathies are with the schools. I feel they have done a much better job in education than industry has, or the average graduate has done for himself considering the opportunities he has for self-improvement. I have raised some questions which I hope may stimulate further progress—the possible elimination of unnecessary and burdensome accumulation of knowledge on the part of the student, improved pedagogical methods, a better mastery of time, and a reshaping of some of the academic and business courses to make them of more interest and value to the student.

But perfect the four-year undergraduate course as we may, the graduating student should be deeply conscious of the fact that it only forms a foundation for his post-college education and he should undertake to lay out a program for himself which will insure progressive improvement.

First, he must decide whether he will continue his post-college education in an educational institution or while gainfully employed in industry, and in making this decision he will find his professors most helpful.

If he decides to continue in school, and I might say that more are finding it advisable to continue for an additional one, two, or three years, he still will have the advantage of close supervision and he can defer the actual plan of his later development.

If he does not continue in school, and a large majority do not find this advisable at the present time, he will find industry very anxious to coöperate with him in his further education and development. I do not feel industry at large has done as good a job in education as the educational institutions have, but most large concerns have very good educational programs and are improving in this regard. In one respect I believe they can and do do a better job, and that is attention to each individual.

But industry's educational program cannot be completely successful without the whole-hearted interest and coöperation of the student engineer, and I fear too many have the deep-seated feeling that their studying days are over instead of just fairly begun. Not enough of the newly graduated engineers join the Founder Societies. They have not been sold on the idea that they are members of a profession and that to obtain benefits from the professional societies they must be members and put something into it. Possibly the Founder Societies should devote more effort toward activities, meetings, and papers which would be of greater interest and help to these young engineers, although my feeling is that they are doing an exceptionally good job in this direction.

Most large industrial concerns have programs for the continuance of education of the engineering graduate. A brief outline of the General Electric plan might be helpful to the young engineer entering, or about to enter, industry, and to those who are interested in post-college engineering education.

The basis of the plan is that the technical graduate is eligible for any position in the Company from the Chairman of the Board down. It is expected that engineering graduates will enter the Company, learn the business in all its phases and eventually take over the operation and management. This embraces highly technical men with a bent for research and development—ingenious men with a practical and economic bent to take the new knowledge and science and experiment, and the new materials and processes resulting from research and development and convert them into commercial product designs; practical and reliable fellows to follow them through production; men with a flair for machines, men, and management to superintend the manufacture; men with com-

mercial instinct to sell and distribute the products; and men who will develop into managers and executives.

Since success depends upon ability and opportunity and we do not know in exactly what direction the opportunity for each individual lies, we consider the success of any particular individual in the Company is somewhat proportional to his adaptability. This, of course, does not apply to graduate students entering the Research Laboratory or some other department where they will continue more or less the same type of work they have already been pursuing in their graduate work at school.

Steps are taken so that the break from academic to industrial life will not be too sharp, and this is done through providing clubs, associations, group meetings and group work. This also helps to develop these general qualifications, such as personality, character, initiative, persistance, coöperation, good fellowship, and ability to judge human values, which are so essential to success.

We are expecting a great deal of the engineering graduate, collectively speaking, but it is apparent there is no one specification covering the engineering graduate to which the school can work.

We deliberately try to choose men with these different qualifications and aptitudes and then through our educational courses and training plans we try to develop them for these various activities. We have one basic rule—the man should earn his way as he develops—he does better if he feels he is earning his way and knows it. It is management's job to fit these various individuals into a smoothly working pattern—it requires judgment, tolerance, patience, and, above all, human understanding on the part of management and the individual.

With us, all engineering graduates are started in the test course, which averages from one year to fifteen months, and which carries with it classroom work in business, electrical engineering and mechanical engineering. The Test provides an excellent medium to acclimate, as it were, the newly graduated engineer to manufacturing and its problems. It also provides excellent training in working with others. The outstanding benefit, however, is that it teaches the man to assume responsibility, as all test work in the General Electric Company is carried out by student engineers except certain routine work which carries but little responsibility and has nothing to contribute to the development of the engineer. While in Test the student engineer must work under the direction of the man in charge of a particular test and he must also take charge of test and have the direction of others.

During this period approximately 50 per cent find positions in industry outside the Company and the others are transferred to some department within the Company. Most of them start in the

engineering department even though they may be scheduled for the commercial or manufacturing departments later. About 10 per cent take a three-year course in advanced engineering, the first year of which is spent in test and the next two years in assignments to various engineering departments. This group will form the technical foundation of our Company. An equivalent number take a commercial course. We have a large number of other specific courses.

Once assigned to a department, these young men are made to feel they are a responsible part of the Company. They are periodically rated and we try to load them with responsibility as rapidly as they can carry it. However, it is only at this period that one finds out the real ability of the man to do things and progress. There is a wide variation in the men and in ten years we find variations in salaries of more than two to one. But we have built a large complex operation and it must be kept going, and to keep it going we need men of widely different abilities, aptitudes and training.

I am much more concerned about our job or industry's job in developing these young men than I am in the job of the educational institution.

After all, our objective is manufacturing—turning out goods—and it requires a special effort and a long range view to take up the task where the educational institution left off—of continuing the education and development of these young men.

But, it is to industry's advantage to make the individual effective and efficient and therefore we take a personal interest in each man and we have a pride in bringing him through. Here, I believe, we have the opportunity to do a better job than the school, for the reason that we choose our men more carefully than the school can and we train them on the job.

It is my feeling that through some forty years of effort to improve the educational program within the General Electric Company we are doing a continually better job, but it must be emphasized that the success of our program depends largely upon the individual himself, particularly his attitude toward continued study and self-improvement. This is particularly so in his later development, where no specific educational program is provided and the individual is left very much upon his own resources.

It is probable we and others could go further in the development of executives. When one accepts responsibility, he also assumes an obligation, and the carrying out of this obligation along with the many and varied administrative duties is not easy or pleasant to one thrust too suddenly into an executive position, even though he has the basic qualifications required. Furthermore, it

is probable that under these conditions the executive is developed at considerable expense to the business.

On the other hand, if one can work gradually into such a position, he develops an aptitude and liking for the executive or managerial duties, and at the same time acquires much valuable experience which will make him more effective.

It appears that the only feasible plan of developing executives is to transfer men who have made a success in one position to some other position requiring more responsibility. The functions of an executive cannot be taught in school, they must be acquired through experience on the job.

We do a certain amount of this, but find it difficult to convince the manager of a department that he can afford to allow one of his most promising young men, who has already proven himself, to be taken away from him and to be assigned to another department. This phase of the later development of the engineer is something that most large concerns should give further attention to.

I would like to sum up the latter part of this paper with the statement that one's whole life is education. The four-year college course is only a beginning or a foundation for an engineering career. Post-college education offers many more possibilities in the development of the engineer than are being taken advantage of, and industry, and particularly the engineering graduate himself, should devote more effort to progress in this direction.

OUR RESEARCH SYSTEM *

By HAROLD VAGTBORG

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We are gathered here today under circumstances vastly different than those of 2,000 years ago when the Romans assembled for discussion of current problems. The mode of living has entirely changed. Nevertheless, the Romans felt they were living in an era of highly developed culture and industrial progress. True, they were bent on learning more of the secrets of nature and as compared with contemporary peoples their transportation and communication systems, implements of war, materials of construction and public utilities were the marvels of the age. Yet how different from those of today. The developments of their era were the outgrowth of the discoveries of previous generations just as the fruits of research which we enjoy today are largely the outgrowth of discoveries of the past thousands of years. So let us not have any feeling of superiority over the Romans. Our most able scientists today could not have made their specific present-age contributions at that time, but they probably would have been the men who would have made the then important discoveries.

Let us step back to the era of the Cave Man 50,000 years ago. How superior he felt to all other creatures that roamed the earth. He had tools with which to work and hunt and his most valued possession, fire, to serve and warm him.

Of the many differences in the modes of living through the ages, the difference in the means of transportation is typical. The Cave Man moved about on foot, the Roman went to his meetings in a beautifully wrought, horse-drawn chariot and we came to this meeting by airplane, train, or the automobile with its steering wheel made of a recently discovered plastic, its enduring finish made from lacquer obtained possibly from the spruce tree, and many other new features too numerous to mention which make it possible for us to travel in comfort and safety at ten-fold the speed of early means of transportation.

Human emotions have remained about constant through the ages but the way of living has drastically changed—changes which have been brought about by chance discoveries or the results of per-

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sistent organized research. Strangely enough, the materials in, on, and above the earth have not changed. We have the same raw materials to work with that past generations had and everything that future generations will have. In other words, nature is no different today than it has been or will be. However, as Dr. Stine of the du Pont Company so aptly puts it, "Mother Nature had a rare sense of humor. She provided man with the materials with which to produce virtually anything his mind could conceive—but she omitted the labels. She scrambled, concealed and disguised her gifts with diabolical cunning. She hid her secrets in the least obvious places and challenged man to fit together the colossal jigsaw puzzle she had created."

As W. W. Campbell has so well stated, "The scientist engaging in research work is looking for something that already exists. He does not invent the truth, he does not develop the truth, he does not do anything whatever to the truth except to uncover it or discover it, and expose it to the comprehension of his fellowmen. . . ."

The things we have today were made possible because with a background of thousands of years of scientific development man could conceive of such things as the airplane, plastics, and radio long before he had them and thereby had a goal toward which to work. What is new to us will be basic to the coming generations and the always active human mind will conceive of new things and will ultimately possess them—things which we today are utterly incapable of even imagining, let alone predicting. Occasionally someone attempts to draw a picture of what our mode of living will be 100 years from now. You will notice that these are merely a projection of the things we have now. Such a picture drawn 100 years ago for the year 1940 would undoubtedly have missed completely the airplane, the automobile, radio, television, electric refrigeration—but why go further? And as to the future—only time will tell.

Research—possibly not as such in name—began with man. The tempo was extremely slow in the early days with only an occasional beat to mark a new discovery as the thousands of years rolled by. First came fire and then the discoveries of what fire could do to the simpler materials. The beats came at long intervals—suddenly and unknowingly—because discoveries were generally accidental. Early man learned how to remove iron and copper from ore with heat. He began to identify more and more of the materials of the earth and his ability to reveal the secrets of nature increased. Research begins to take a more definite form. Many discoveries were kept secret and passed on from father to son. Others try to imitate but often something is missing. These early beginnings led to the age of artisanship and craftsmanship. But the research tempo

quickens and science marches on. The period of "cut and try" opens and man begins actually to look for new secrets of nature rather than just to stumble onto them. Colt whittled the first revolver out of a piece of wood while he was whiling away the long hours on a sea journey. Fulton's first steamboat model was made in much the same way. At the same time, in many shops and laboratories, workers were mixing ingredients unceasingly hoping that each time the desired result would occur. Very often something would happen that was entirely different from what was expected and a discovery of great importance would add to our knowledge of science.

Today the research approach is more basically sound. A problem is carefully analyzed and then segregated into its component parts for study. As missing links are supplied a complex picture becomes clear and a new discovery is added to our store of knowledge. This procedure has greatly increased the research tempo and its productiveness is accelerating. Today the world is research conscious and an activity which began in the laboratories of our educational institutions in a small way has become the pilot of industry. Many prefer to think of research as an industry in itself—one employing almost 50,000 workers and spending about $250,000,000 in 1939 in the United States alone.

But what of the research incentive? It certainly must exist to demand such attention and must take a variety of forms to engage a host of miscellaneous types of workers in both our educational institutions and in industry. The incentives are many, of course, but the more obvious will include the following:

(1) *Success of past developments.* The overall success of research activities during the past 300 years is a great stimulation to probe further the mysteries of nature.

(2) *Rapid growth in recent years of new industries.* Radio, television and the airplane spur us on to find new discoveries of the same importance.

(3) *Appreciation of future possibilities by use of newly available scientific tools.* X-ray diffraction, high speed photography and polarized light are just a few of these. What will they produce in the way of new and amazing developments?

(4) *Research may hold the answer to the conservation of existing materials and certainly does for the development of new ones.* How can we prevent great annual loss due to oxidation of iron and steel structures? What can be done to enable us to get more than 10 per cent of the power effectiveness of gasoline?

(5) *Social aspects of research.* There are three frontiers of development of employment—land, population increase, and new industries through research. In previous years our prosperity was

due in a large measure to the first two and it becomes increasingly important to create new industries through research if our prosperity is to continue.

(6) *Research is the life blood of our free competitive system.* Industry is dependent for its continued growth and success on its ability to produce new and better products at lower cost.

(7) *Research offers not only monetary reward but professional advancement and recognition.* Of these two it is believed that the research workers in our educational institutions put much greater stress on the latter than the former.

We have considered briefly the background of research—its development, the magnitude of its present activities, its products and its incentives. In considering the system under which it operates we shall limit ourselves to scientific research in the field of engineering applications.

In discussing the system under which research is carried on in this country it seems desirable to classify the research agencies and compare their objectives. The following classification is generally acceptable and provides for all research activities of any significance.

Individuals
Companies
Associations
Consulting and Testing Laboratories
Research Institutes
Foundations and Councils
Societies
Government Bureaus
Universities and Colleges

Individuals.—It is true that practically every research development or discovery is the product of individual effort. This classification refers to the scientist working in a private laboratory operated by his own resources. We are all familiar with numerous examples of this kind and it is probably safe to say that most of the significant early developments in transportation, communication and manufacturing processes came about in this manner.

These laboratories are more contemporary with those of past decades than the present and their workers were urged on by enthusiasm for their work and the desire to serve their fellowmen. Edison, Marconi, Fulton, Newton and Franklin are typical of these and many of our great industries are the outcome of their efforts. The same kind of men are at work today contributing much to our research progress but in general are associated with industrial organizations or educational institutions where they have found advantages in having co-workers and extensive facilities.

Companies.—The increased rate of the revealing of nature's secrets has led to the creation of numerous research departments in corporations in recent years. At the present time by far the largest proportion of industrial research is done by these laboratories. The National Research Council reports that at the present time there are over 1,700 of these laboratories employing about 40,000 workers and expending an estimated $200,000,000 annually. The steel and the automotive industries each spent about $10,000,000 in research in 1939 and in the same year the chemical industry alone spent $20,000,000, which is equivalent to $4.30 per $100 of income. Numerous individual companies expend over $1,000,000 per year and the fact that appropriations for research are increased indicates lucrative returns.

A substantial proportion of corporate research expenditures covers projects which are "farmed out" to colleges and universities and to research institutes. Many of these projects are of a long-term fundamental nature and are ideally suited to investigation in laboratories away from the numerous interruptions generally caused by pressing production problems in corporation laboratories.

Scientific research has opened new fields for the employment of thousands by the development of new products which have created new industries. Fifteen of the major industries of today have been developed since 1880 and it has been estimated that these have created, directly or indirectly, 15,000,000 new jobs—in other words one out of every four persons gainfully employed today owes his job to an industry which grew out of a research development since 1880.

Someone might say, however, that scientific research has also crippled other industries and thereby reduced employment. A good example of the unsoundness of this argument is that when the horse and buggy industry was at its height in 1900 it gave employment to approximately 1,000,000 persons, whereas at present the automotive industry, which replaced it, employs over 6,000,000.

At any rate, the industries have found that scientific research is essential to the improvement of existing products and the development of new ones. Industry's big problem today seems to be the securing of proper personnel and naturally it looks to our educational institutions for major assistance. There also seems to be a tendency on the part of industry to turn more and more to university and college laboratories for direct assistance on research problems and to appropriate funds for this work in increasing amounts.

Consulting and Testing Laboratories.—It has been estimated that about 250 of these organizations are in operation in this coun-

try today. They are performing an important day by day service to industry primarily in the handling of physical tests and analyses requiring special facilities and personnel. A great number of the smaller industrial corporations not justified in maintaining their own laboratories have found such organizations most valuable. There are numerous instances where corporations of this kind have their routine analyses and testing problems handled by commercial testing laboratories and turn their long-term research projects over to universities or research institutes.

This classification also includes a group of consulting laboratories, each of which is generally specialized in a particular scientific field and is qualified to render advisory and research service.

Unfortunately, those in this classification have a real problem in that they claim non-profit and often tax supported institutions such as our universities and colleges are in direct competition with them. It is hoped a solution satisfactory to all will be worked out in time.

Research Institutes.—Research institutes are generally endowed, non-profit organizations operated primarily to serve industry on long-term applied research projects and may or may not be affiliated with educational institutions. Typical of these is the Mellon Institute of Industrial Research, affiliated with the University of Pittsburgh; the Armour Research Foundation, affiliated with the Illinois Institute of Technology; and Battelle Memorial Institute which has no educational affiliation but has a working arrangement with the Ohio State University.

Not being tax supported, these institutions can enter into agreements with sponsors which provide for outright patent protection and keeping the results confidential where these features are desired. With few exceptions the research workers are full-time staff members of the institutes. An affiliation or working arrangement between a research institute and an educational institution is of mutual benefit in many ways. The staff of one strengthens the staff of the other and the inter-exchange of equipment and facilities not only improves the industrial research service rendered by the institute to outside agencies but also makes more extended facilities for fundamental research available to the staff and graduate students of the educational institutions. These institutes also award attractive fellowships to deserving graduate students who are assigned part time assistantships in laboratories and carry on their advanced work in the affiliated institution. It is particularly noteworthy that students who have completed such a program usually have developed an excellent research technique and their experience on applied research problems makes them very valuable in research positions in industry. During 1939 approximately 250

corporations had long-term projects placed with research institutes.

The research foundations of educational institutions have much in common with the research institute. For purposes of clarity, however, these are discussed under the classification of "universities and colleges."

Foundations and Councils.—The foundations of this classification refer to the several hundred endowed organizations which sponsor research. Typical of these are Rockefeller Foundation, Carnegie Corporation, Carnegie Institute, the Engineering Foundation, and the Research Corporation of New York.

All of these are notable for the aid they have given, primarily in the support of fundamental research investigations in our educational institutions.

The National Research Council is included in this classification although its activities are much broader for it operates in many fields of which engineering is one. Not only is it the recognized national research clearing house but it also makes grants to various research agencies including universities and colleges. The National Research Council publishes from time to time an important directory under the title, "Industrial Research Laboratories in the United States," and has recently published a listing of research grants by industrial corporations to universities and colleges as well as to other research agencies. The Council also sponsors the Industrial Research Institute which is a national organization of industrial research directors and executives.

Societies.—Most of our national societies have funds which are granted usually through a research committee, to institutions equipped to do research of basic importance to the society. Such committees may also serve in correlating national and international research activities having a bearing on the functions of the society. In many instances a committee of one society will work jointly with a committee of one or more other societies in the sponsoring of research having mutual interest. Much of our engineering progress in past years has been made possible by the activities of this group.

Government Bureaus.—A basic activity of any government is to carry on research which has a bearing on the general welfare of its people. The budget for research by our national government agencies during the year 1939 was approximately $60,000,000 and was distributed about as follows:

Engineering	36%
Surveys	16%
Physical Sciences	4%
Natural Sciences	39%
Public Health	5%
TOTAL	100%

Government research generally covers those fields which private industry either has no incentive or no reason to enter on a broad scale. It is the kind of research that is carried on to improve our comforts of living, increase our national security, and conserve our natural resources. Typical of these fields are, national defense, mining and agriculture. The outstanding bureaus which engineers are most familiar with are the Bureau of Standards and the Bureau of Mines.

Universities and Colleges.—On the occasion of the Harvard Tercentinary celebration in 1936 six industrial leaders, Walter S. Gifford, President, American Telephone and Telegraph Company; Alfred P. Sloan, President, General Motors Corporation; Thomas G. Watson, President, International Business Machines Corporation; Pierre S. du Pont, Chairman of the Board, E. I. du Pont de Nemours Company; Owen D. Young, Chairman of the Board, General Electric Company; and Walter C. Teagle, President, Standard Oil Company of New Jersey, addressed a letter to President Conant which included the following passage:

> The large and increasing number of university-trained men in industry and business gives ample evidence of the great influence that university education has had on industrial progress. In addition, a different sort of contribution has been made that in promise and initial achievement seems to be of almost revolutionary importance.
>
> Scientific research is still young, even in the life of the universities which are primarily important for its existence. Having caught the spirit of research from the universities, industries have applied its methods to their own affairs—in many cases with amazing results. The last quarter century has seen the number of industrial research laboratories in this country grow from a mere handful to more than 1,500 and the number is rapidly increasing.
>
> Without the evolution of research in the universities, these industrial laboratories might never have come into existence. Besides the very idea of research the universities have furnished industry with men possessing knowledge not only of the underlying scientific facts and theories but of the methods and techniques of research. From the universities also flow much of the basic knowledge of science on which modern technical industry has been built and will build in the future.

Let not the statement, "having caught the spirit of research from the universities, industries have applied its methods to their own affairs . . ." escape us. It is not only a statement of commendation but also a challenge that our educational institutions must accept. They must continue to formulate the spirit of research upon which industry will always be dependent.

It is generally agreed that our increasing knowledge of the laws of science has been largely brought about by the active par-

ticipation in research by the faculties of our educational institutions and that if progress is to continue and these institutions are to produce properly qualified graduates, their faculties must continue or even increase participation in research, particularly in those fields of a fundamental nature. The extent to which our faculties should engage in research is a controversial matter at the present time but since the title of this discussion deals with our research system as it is—and not what some of us might think it ought to be—there is no need to present arguments pro and con. It cannot be denied, however, that as the research tempo increases, industry is increasing its demands for graduates who have an understanding of so-called research technique and an appreciation of the research approach.

Research work in our educational institutions today is carried on in one or two ways: either as individual activity in a field in which the worker is interested and urged on by his enthusiasm for his particular subject, or as part of a sponsored plan. In any event the reputation of an institution seems to depend to a large extent upon its research productiveness and most institutions encourage research by their faculties, some even tending to make it a prerequisite for appointment.

Several plans for sponsored research in our educational institutions are in existence today. In one instance the worker or faculty member is given a grant, either by the institution or by an outside agency. It is generally conceded that most of the research grants that go to our universities and colleges today are given not because of the standing of the institution entirely but because of the reputation of a particular faculty member who has unusual capabilities and facilities for the carrying on of research in the particular field in which the outside agency making the grant is interested.

A second case refers to those institutions which receive support from governmental agencies for work in specific fields. These are mainly state or tax-supported institutions which function partly to render research services in agriculture and the mechanical arts to their communities through grants from the state or government.

A third instance of a sponsored plan covers organized research in educational institutions and often takes the form of an experimental engineering station. An organized research program of this kind offers many incentives for industrial participation as evidenced by the fact that many of these organizations receive substantial research support from individuals, corporations, associations and the other research agencies.

A great deal of research is carried on where patents are not involved and the publication of results is desired by all parties. This is particularly true of all fundamental research, industrial

research sponsored by manufacturing associations, and research made possible by grants from societies and other agencies. However, complications occasionally arise under this system where individual corporations want patent protection and the results kept confidential.

A modification of the last mentioned form of organized research somewhat approaches the research institute previously mentioned and is generally known as the research foundation of the college or university. Typical of these is the Research Foundation of Ohio State University, the Research Foundation of the University of Wisconsin, the Purdue Research Foundation, and The Institute of Research of Lehigh University. There are many others, of course, and new ones are being established in increasing numbers. Generally speaking, these foundations are placed under a director who establishes contacts with industry and other grant-giving research agencies and through faculty coördination research projects are undertaken by agreements which cover patent policies and publication rights.

The increased tendency to organize research activities in educational institutions during the last decade has been brought about by the necessity of adopting well defined policies in regard to inventions made by faculty members. Some have predicted that in another ten or twenty years all scientific educational institutions will have clearly defined patent policies. In June, 1938, at College Station, Texas, there was presented before the Conference on Engineering Research, S. P. E. E., a paper entitled "When Research Leads to Patents" by Clifford B. LePage, Assistant Secretary, American Society of Mechanical Engineers. This paper and the published discussions of it deal so well with the problem of patents that repetition here is unnecessary. To those interested in patent policies reference is made to "University Patent Policies" by Archie MacInnes Palmer, printed in The Journal of the Patent Office Society for February, 1934, and "University Patent Policies" by Richard Spencer, Lecturer on Patents, Northwestern University Law School and published in 1939.

Before passing from the subject of patents it seems desirable to state that several educational institutions such as Massachusetts Institute of Technology and Princeton University have working arrangements with the Research Corporation of New York whereby the inventions of their faculties are generally turned over to that corporation and any proceeds from commercialization accrue in a fixed manner to the principals who are involved.

Much of the research work carried on in educational institutions is self-sponsored and it is difficult to ascertain with any degree of accuracy the support given by outside agencies. Some general

information is available. About 110 individual companies in the field of the chemical industry and 40 trade associations made research grants to educational institutions in 1939. Numerous trade associations, engineering societies and miscellaneous industries also made grants. Approximately 200 college laboratories are used not only for instruction but for fundamental research, applied industrial research and to a considerable extent for commercial testing.

The educational institutions have a real opportunity and almost a responsibility to carry on the bulk of fundamental research. It is natural that they should for it gives recognition to the institution and opportunity for the professional advancement of its faculty members. Industry is somewhat reluctant to carry on any large amount of fundamental research because it feels that direct monetary returns come from applied research. Then, too, industry has to a large extent led itself to believe that it is fitting and proper that tax supported institutions should carry the brunt of expense of fundamental research. Educators, of course, rightfully find fault with such a policy and upon them falls the responsibility of selling the idea that grants for fundamental research must come in increased amounts from industry. Recent indications are that there has been some improvement in this direction.

In any event, most of the fundamental research work will undoubtedly always be done in our educational institutions with industry becoming inclined to support more and more of its cost and at the same time being increasingly willing to support almost the entire cost of applied research.

So we find that industry is almost wholly dependent upon the new discoveries made in fundamental research and that the fruits of research in our educational institutions contribute in a major way to industrial progress. Sponsorship of both fundamental and applied research, therefore, must be continued at an ever increasing rate for without new discoveries coming regularly, applied research will stagnate and the benefits of research progress to mankind will wane.

REPORT OF CONFERENCE ON MINERAL TECHNOLOGY

At the meeting at Berkeley last summer there were six sessions of the Mineral Technology sub-committees as follows:

1. Fuels Utilization: The importance of teaching Fuels Utilization, presided over by A. J. Carlson, Professor of Fuels Utilization at the University of California. This meeting had a good attendance, with representatives of the industry present. They and the teachers took part in the discussion.

2. Geology: The accrediting of Geology in the mining engineering curriculum. G. M. Butler, Dean and Professor of Geology at the University of Arizona, presided. There were two meetings of this sub-committee, and at each there was a good attendance. I quote from Dr. Butler's remarks the following as being of general interest "courses called geological engineering will not be accredited by E. C. P. D. unless they meet the minimum requirements of all engineering curricula. These requirements involve not merely a good foundation in the basic sciences, but also the erection of a superstructure on that foundation in the junior and senior years. We do not insist that this superstructure be a large one but that no course that does not include some subjects in the last two years which require the application of mathematics and physics can rightfully be called engineering, no matter how well the foundation has been laid. I think that no announcement has ever been made as to just how many units of such advanced courses must be included, but I am inclined to believe that the equivalent of a semester of them would be the irreducible minimum." I believe that a majority of those present were in agreement with Dr. Butler's views.

3. Petroleum Engineering: Scope and content of Petroleum Engineering curriculum. Professor Lester C. Uren presided and the attendance was large, with many representatives of the industry present. Eugene A. Stephenson, Head of Dept. of Petroleum Engineering at University of Kansas, presented a paper on the Scope and Content of the Petroleum Engineering Curriculum which is given herewith:

4. Metallurgy: Recent trends and practice in mineral concentration, presented by Le Verne Zeigler, Consulting Engineer, Wallace, Idaho. Professor Duschak presided. Mr. Zeigler has designed over two hundred concentrating plants and mills in the

United States and in foreign countries, and he gave numerous illustrations taken from his own experience, and data which were very valuable. Herewith is a summary of his talk.

Concentration of minerals has evolved, through stages, from crude handsorting of ores, gravity separation by hand jigging in water, to mechanical jigs, tabling and vanning of slimes to the modern practice of concentration by flotation. In many instances all of these methods are still in use. Each ore is an individual problem and there is no set practice or process which can be applied economically. Froth flotation of minerals has become by far the most important method of concentration not only for metallic sulphides, but for certain oxidized metallics and non-metallics.

In the concentration process, initial preparation of the ores by crushing, sizing, grinding and classification is necessary. Coarse crushing is accomplished either by jaw or gyratory types of crushers and some enormous machines have been developed.

Shaking or vibrating screens have practically replaced the older revolving screens in crushing plants, not only for coarse screening, but for sizes as fine as 60 mesh.

For secondary crushing, the cone type crusher has nearly supplanted all other types, but rolls are used in notable instances when crushing is carried as far as 10 mesh.

In recent practice, there has been a trend toward finer crushing for ball or rod mill feed. The physical characteristics of the ore are a definite factor in this respect.

Both ball and rod mills are used for grinding and Huntington and Chilean types have almost completely disappeared. For sizing of the ground product, classifiers of the Dorr, Akins, or Esperanza type are generally used in closed circuit with the grinding unit. Circulating loads as high as 1000 per cent of the original feed are common for very fine grinding, although for coarser sizes 300 to 400 per cent is sufficient and economical.

A wide variety of abrasion resistant materials are used for ball mill liners and balls. The development of chrome molybdenum steel has been an important factor in reducing liner costs, especially in mills where very hard sharp ore is treated. For grinding balls, forged carbon and alloy steel are widely used and there has been a consistent reduction in the manufactured cost of these. In several mining districts and in some very large single operations, white iron cast balls in medium sizes are used with low costs due to cheap scrap iron supplies and low manufacturing costs.

Flotation has superceded in capacity all other methods of concentration. The type of apparatus varies widely. Generally, the low grade copper concentrators use pneumatic cells while lead, zinc, iron and more complex separations require some sort of mechanical

or combined mechanical and sub-aerated flotation machines. Recent trends have been towards larger cells and units.

Reagents for flotation which have now become standardized to a high degree, consist principally of frothers, collectors, inhibitors, etc. Cresylic acid is probably the most commonly used frother and is used more extensively than pine oil for this purpose. Amyl, propyl, and butyl alcohols are coming into favor where a delicate selection of mineral is required. Xanthates of the various alcohols, as well as the phosphorous sulphides, are used extensively for collectors. Lime and soda ash are widely employed as reagents to maintain alkalinity in the flotation process. In recent operations, very few operations are run in acid circuits.

Lime, zinc sulphate and cyanide are the principal reagents for the inhibition of zinc and iron minerals in flotation. For the non-sulphide minerals, saponified cotton seed oil and oleic acid are most commonly used. Several commercial chemical companies have put on the market standardized reagents for different purposes and have made available a service that has long been needed in the concentration by flotation.

Extraction of moisture from flotation concentrates is accomplished almost universally by thickening and filtering. Both the continuous drum and leaf type filters are used.

Gravity concentration is making a strong comeback with the development of the Sink and Float process. This process is used mainly for the benefication of ores in coarse sizes as well as cleaning or washing coal. Several large plants are in operation, recently constructed, to treat lead and zinc ores as well as one notable plant concentrating iron ore.

The art of concentration of minerals has become more and more important with the exhaustion of high grade mineral deposits. It is recognized now as a highly technical subject and trained specialists are in demand in this industry.

5. Mining: At this time, I heard of the arrival from Manila of Mr. Pomeroy Merrill, Consulting Engineer, and at my request he gave a most interesting talk on the Technology, Economics and Politics of Mining in Asia, where his experience has been very considerable.

6. Metallurgy: *Round Table Discussion* led by L. H. Duschak, Professor of Metallurgy, University of California, on teaching nonferrous metallurgy. There was considerable discussion presented, all of which was much to the point. Unfortunately there were no minutes taken but there was a good attendance and a lively discussion. Professors Uren and Duschak and Carlson were present which helped materially to keep the discussion very lively.

Petroleum Engineering, which is also commonly designated as Petroleum Production Engineering, is one of the younger branches of the engineering profession, and as such is probably still suffering from growing pains, while it seeks to find the precise fields of endeavor to which it may be applied. Although it originally stemmed from geology, during its growth to the present more or less generally accepted type of engineering training which it signifies, it has diverged farther and farther from the geological profession. Its case is somewhat analogous to that of Chemical Engineering, which for many years was ridiculed by the mechanical engineering profession, but which has nevertheless held true to its course, until it is today one of the broadest types of engineering training.

The special field in which geology was at first important had to do with the selection of preferred sites for drilling and exploration, but as these functions have gradually been supplanted in large measure by the work of the geophysicist, many geologists have devoted themselves to the study of the engineering principles which are strictly within the province of the production engineer. For example, a study of the content of the bulletins of the A. A. P. G. for the past seven years shows that the geologist has come to regard core analyses, verticality control, electrical coring devices, interpretation of water analyses, proof of the type of reservoir energy, estimation of oil and gas reserves, drainage problems, spacing problems, drilling time in rotary wells, etc., as part of his special field. The following references to specific articles will illustrate the point which has just been made:

WILDE, H. D., JR., and LAHEE, F. H. "Simple Principles of Efficient Oil Field Development." *A. A. P. G. Bull.*, Vol. 17, No. 8, pp. 981–1002, August, 1933.

PORTER, W. W., II. "Influence of Speed of Migration of Oil on Water Encroachment at Casmalia, California." *A. A. P. G. Bull.*, Vol. 17, No. 9, pp. 1133–36, September, 1933.

RUSSELL, WILLIAM L. "Subsurface Concentration of Chloride Brines." *A. A. P. G. Bull.*, Vol. 17, No. 10, pp. 1213–28, October, 1933.

WRIGHT, R. "Jamin Effect in Oil Production." *A. A. P. G. Bull.*, Vol. 17, No. 12, pp. 1521–26, December, 1933.

WYCKOFF, BOTSET, MUSKAT, REED. "Measurement of Permeability of Porous Media." *A. A. P. G. Bull.*, Vol. 18, No. 2, pp. 161–90, February, 1934.

BRACE, O. L. "Factors Governing Estimation of Recoverable Oil Reserves in Sand Fields." *A. A. P. G. Bull.*, Vol. 18, No. 3, pp. 343–357, March, 1934.

CHENEY, M. G. "Economic Spacing of Oil Wells." *A. A. P. G. Bull.*, Vol. 19, No. 6, pp. 876–99, June, 1935.

CLAPP, F. G. "Safety of Water-Flooding Pressure at Bradford, Pennsylvania." *A. A. P. G. Bull.*, Vol. 19, No. 6, pp. 793–852, June, 1935.

NUTTING, P. G. "Technical Bases of Bleaching-Clay Industry." *A. A. P. G. Bull.*, Vol. 19, No. 7, pp. 1043–52, July, 1935.

LYNTON, E. D. "Laboratory Orientation of Well Cores by Their Magnetic Polarity." *A. A. P. G. Bull.*, Vol. 21, No. 5, pp. 580–615, May, 1936.

DEUSSEN, A., and GUYOD, H. "Use of Temperature Measurement for Cementing Control and Correlations in Drill Holes." *A. A. P. G. Bull.*, Vol. 21, No. 6, pp. 789–805, June, 1937.

HEDBERG, H. D. "Evaluation of Petroleum in Oil Sands by Its Index of Refraction." *A. A. P. G. Bull.*, Vol. 21, No. 11, pp. 1464–76, November, 1937.

WILDER, N. M. "Practical Repressuring." *A. A. P. G. Bull.*, Vol. 22, No. 2, pp. 189–200, February, 1938.

HIESETAND, T. C., and NICHOLS, P. B. "Drilling-Time Data in Rotary Practice." *A. A. P. G. Bull.*, Vol. 23, No. 12, pp. 1820–34, December, 1939.

While the profession has been establishing its foundation on a broader base each year, excellent publications in the form of textbooks by Professors Uren and Cloud have appeared, although both of these still lack what the writer considers one of the essentials of any engineering course, *i.e.*, specific problems to be solved by the student. The annual volumes and occasional publications issued by the A. I. M. E. and the A. P. I., during the past ten years have served as media for the dissemination of the results of important researches prosecuted by the various educational institutions, or sponsored by the leading oil and gas companies, the manufacturers of oil field supplies, and the A. P. I. itself. The *Journal of Industrial and Engineering Chemistry* also has been a fruitful source of technical material, which has definite application to oil and gas production problems. Careful perusal of the above publications shows that the trend of applied production engineering has been definitely towards a more adequate understanding of the behavior of the complex mixtures of hydrocarbons within the reservoirs, with less emphasis on their behavior after they reach the well bore. Possibly the latter now merits intensive study.

The practical application of the technical data which have been made available through the above media requires a working knowledge of chemistry, physics, mathematics, geology, thermodynamics, hydrodynamics, and many phases of chemical engineering. If changes are contemplated which will incorporate certain courses given in the department of mechanical engineering, it seems appropriate to inquire as to what shall then be deleted from the production engineering curricula. Is there any course in mechanical engineering which touches physical chemistry, or colloidal chemistry, the extensive application of the phase rule, pressure-volume-temperature relations at high pressures, the modifications in the physical properties and behavior of oil-gas solutions due to changes in concentration of a particular component, the flow of heterogeneous fluids through porous media, or which makes any use of geology?

It is recognized that many petroleum engineers do not enter the field of production, but become salesmen of oil-field equipment, or

associate themselves with some of the specialized types of oil-field services, and that the production engineer is frequently called upon to exercise his judgment in the selection of equipment, a judgment which is unquestionably improved through training similar to that of the mechanical engineer. It is also fully recognized that the industry has a definite place within its varied activities for mechanical engineers, electrical engineers, geologists, and civil engineers, but it is greatly to be questioned whether it is wise to sacrifice any of the basic elements of petroleum engineering to any other profession.

The problem which confronts us, if there is a problem at all, resolves into the questions as to (1) whether petroleum production engineers are to be men whose specialty is to understand and control reservoir performance, and through the use of engineering technique be able to so operate wells and reservoirs (or tell someone else how to do these things) that larger ultimate recoveries may be obtained, and that full advantage be taken of the forces of nature to reduce the cost of production; or (2) shall this unique field of engineering be discarded, and the training of men for the production of oil and gas revert to the predominantly mechanical side, with its much more limited scope; or (3) possibly a third alternative may be considered under the title Petroleum Production Option in Mechanical Engineering, but which will still preserve those important elements of the present production engineering curricula that are scarcely touched upon in the mechanical engineering courses.

A question comes to the mind of the writer as to a possible danger which may arise if the production engineering course departs from the thoroughly scientific and comprehensive base on which it is now founded. That question may be stated thus: Will it not soon become necessary for us to defend the existence of departments dealing principally with production engineering? Will not any action which tends to introduce more mechanical engineering into the production curriculum actually invite the suspension of the departments which at the present time stress the fundamental scientific training which enables its graduates to comprehend and utilize efficiently the forces which bring about the production of oil and gas?

Discussion may be further stimulated by asking whether it might not be wiser to make the production engineering courses even more exacting than is now the case, by requiring more mathematics, at least through differential equations, more physical chemistry, especially the study of colloids, more general use of equilibrium constants, more instruction in phase equilibrium problems and the pressure-volume-temperature relations of gases at high

pressures and moderately warm temperatures, more attention to solubility-shrinkage relations, an intensified use of specific or case problems in each course in petroleum engineering, such problems drawn directly from field data. If such problems are viewed in the light of the latest scientific researches, which come to us almost weekly in the form of the various technical publications, will not this procedure tend to develop engineers who are invaluable in the production of oil and gas, and whose services will continue to be in demand?

At the early meetings, the Easterners generally did not know the Westerners. To bridge this gap, we had a luncheon or dinner each day of the meeting, which brought the men together and to know each other, with the result that the later meetings did not have to overcome this situation and there was very good fellowship shown as a result.

Inspection trips arranged by the California members for our visiting members were, I am sure, very much appreciated and enjoyed.

RICHARD S. MCCAFFERY,
Chairman

NEW MEMBERS

Associate Institutional Membership: Ohio Mechanics Institute, Cincinnati, Ohio, JOHN T. FAIG, President.

ADAMS, RALPH G., In charge of Courses, Franklin Union Technical Institute, Boston, Mass. R. D. Douglass, B. K. Thorogood.

ALLURED, ROBERT B., Associate Professor of Electrical Engineering, Arkansas Polytechnic College, Russellville, Ark. C. R. Nichols, G. P. Stocker.

GOGLIA, MARIO J., Instructor in Mechanical Engineering, University of Illinois, Urbana, Ill. C. H. Casberg, F. B. Seely.

KANE, MARGARET L., Teacher of English, Wilmington High School, Wilmington, Del. G. R. Beach, T. H. Chilton.

KUNZ, RAYMOND J. F., Assistant Professor of Chemical Engineering, Cooper Union, New York City. A. H. Radasch, L. Perez.

LARGE, GEORGE E., Associate Professor of Civil Engineering, Ohio State University, Columbus, Ohio. F. L. Bishop, Nell McKenry.

LEGAULT, ADRIAN R., Assistant Professor of Civil Engineering, Colorado State College, Ft. Collins, Colo. N. A. Christensen, F. B. Beatty.

MCKEE, WAYNE S., Assistant Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa. W. N. Jones, J. B. Rosenbach.

RUSSELL, JOHN J., Acting Head, Dept. of Chemistry, Franklin Union Technical Institute, Boston, Mass. B. K. Thorogood, R. G. Adams.

SHREVE, DARRELL R., Instructor in Mathematics, Purdue University, Lafayette, Ind. J. N. Arnold, Justus Rising.

SPINDLER, WILLIAM A., Assistant Professor of Metal Processing, University of Michigan, Ann Arbor, Mich. O. W. Boston, W. W. Gilbert.

SPRIEGEL, WM. R., Associate Professor of Management, Chairman of Dept., Northwestern University, Evanston, Ill. O. W. Eshbach, J. F. Calvert.

TURNER, ADLAI S., Professor of Civil Engineering, Arkansas Polytechnic College, Russellville, Ark. C. R. Nichols, G. P. Stocker.

WILLIAMS, JOHN G., Assistant Professor of Engineering Drawing, Arkansas Polytechnic College, Russellville, Ark. C. R. Nichols, G. P. Stocker.

140 individual + 2 institutional members.

ENGINEERING ECONOMY PAGE

Engineering Economy deals with comparisons between technical alternatives in which the differences between the alternatives are expressed as far as practicable in money terms.

EUGENE L. GRANT, Stanford University, *Editor*

WHEN SHALL ENGINEERING ECONOMY BE TAUGHT?

At our conference at Berkeley last June, the suggestion was made that a course in engineering economy might appropriately be given to freshmen. The following extract from the stenographic report of the panel discussion held at the Penn State meeting in 1939 indicates rather general agreement on the opposite viewpoint, that is, that engineering economy should be taught as late in the curriculum as possible:

J. C. G. Seidl (Manhattan College): Engineering economy should be taught as a separate course late in the education of the student. The student in the junior year is still primarily interested in the technical aspects and not in the economy or administration of engineering projects, and if he has presented to him at once both the design and the economy, he will apply most of his time and energy to understanding the design. If, however, engineering economy is delayed to the senior year, the student then has a wider vision of the entire field of engineering and, therefore, will devote more effort to understanding the economy. That is why I say it should be taught as a separate and distinct course, and he should be held responsible in that course only for the economy of his project.

D. B. Prentice (Rose Polytechnic Institute): I agree absolutely with Professor Seidl. I think the subject should be taught as a separate course. But I rather dislike the idea that the two plans are mutually exclusive. It seems to me that the material of engineering economy is of sufficient importance to be taught not only as a separate course, but also brought in by the engineering professors in their design and other subjects, wherever they can.

Chairman F. H. Crabtree (Tufts College): When would you give that course then?

Prentice: We give it in the first semester of the senior year.

Seidl: We give it in the second.

Crabtree: Professor Millard, when do you give it?

C. I. Millard (Cornell University): In the second term of the senior year, and it is entirely an elective course. This time is due to teaching load for one reason. But incidentally, I feel it comes at a time when you have the more mature student to deal with. I can say that of all the courses I have ever taught I have had more enthusiasm in that course than in any other.

R. C. Putnam (Case School of Applied Science): I think the time of giving the course depends somewhat on what you want to do with the course, how you have that course planned. We give the course in the second semester of the senior year, also, for two very definite reasons. One, as Professor Seidl has said, is because of the psychological advantage to the student, and the other is that we use engineering economy as a keystone course which ties together all our engineering. The problems that we use for illustration, the case problems that some of the professors use exclusively, call on all of their engineering work. For example, in electrical engineering our problems involve AC and DC machinery, power factor, accounting, and other subjects which the students will not have completed until the second half of their senior year.

Crabtree: One reason for giving the course earlier might be to draw on the course in teaching subsequent technical courses. For instance, in my water power course, taught in the second semester of the senior year, I make considerable use of the engineering economy which I taught in the first semester.

MECHANICAL ENGINEERING PAGE

I consider the honest engineer the most valuable asset of this government.—Wm. H. Taft.

R. L. SWEIGERT, Georgia School of Technology, *Editor*

OBJECTIVE QUIZZES IN ENGINEERING

V. M. FAIRES

Agricultural and Mechanical College of Texas

(*Continued from the December issue*)

Another type of question is that which gives the student a choice of answers from which he picks the correct answer. When there are only two choices as in

5. The rubbing speed in worm gears (1) does, (2) does not depend on the lead angle _____

the composition of the question is not so difficult. The only trouble is in thinking up the question. Another easy kind to frame is

6. The pitch angle of a crown gear is (1) 45°, (2) 90°, (3) 14½°, (4) 20°, _____

even though several choices are given. But when a number of choices are provided that are not so simple as in 6, I personally find it very difficult to compose statements that are not so obviously wrong as to give themselves away even to the ignorant student. To be effective, the question must not answer itself. Illustrations of this type are:

7. A mask is used on a ratchet (1) to make it operate more quietly, (2) to protect the teeth from breakage, (3) to make the pawl move through a shorter arc, (4) to decrease the movement of the ratchet. _____
8. Increasing the load on a particular journal bearing with thick-film lubrication will (1) increase the eccentricity factor, (2) increase the thickness of the minimum film, (3) decrease the frictional loss, (4) reduce the clearance. _____

Evidently, care must be taken that there is only one correct answer in a group of choices, unless it is indicated that the student should make more than one choice.

I risk making the foregoing statements, even though I have made no study of objective tests, because I believe, despite my limited experience, that teachers of engineering can make excellent use of such questions. Moreover, since these questions are generally difficult to compose and since they probably need to be proved unambiguous by use, it occurred to me that there might be some coöperative effort in this direction. In the field of machine design, the machine design clearing house could inexpensively distribute to all its membership copies of objective questions sent in. If there is enough interest among teachers of machine design, it would not be long before each one has a very adequate file of such questions. It is even conceivable that the resulting collection might be useful in framing examinations for engineering licenses.

As for the other groups in the Mechanical Engineering Division, similar machinery for distributing questions might be set up through their respective committees, the Heat Power Committee, the Manufacturing Processes Committee, and the Mechanical Laboratory Committee. If you approve the plan of coöperative effort, why not tell the chairman of the committee concerned with your field.

Editorial Comment:

Objective type tests and examinations merit considerable attention from those concerned with mechanical engineering education. The call by Professor Faires for coöperative effort in building such tests should be heeded by the Mechanical Engineering Division. In order to initiate such a program it will be advisable to present the background of such tests, to compare them with the traditional type tests, and to point out their limitations, specific advantages, and particularly to bring out the techniques involved in building such tests. Disappointments have occurred in connection with the use of objective type tests because the one preparing such tests was familiar with neither the techniques involved nor the methods of validating the tests. Therefore, in the near future the Page will be devoted to a development of the use of objective type tests.

THE T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE
DIVISION OF ENGINEERING DRAWING

B. M. GREEN, *Editor*, Stanford University

NATIONAL DRAWING COMPETITION

GENERAL REGULATIONS FOR SCHOOL YEAR, 1940–41

Auspices of the Division of Drawing and Descriptive Geometry Society for the Promotion of Engineering Education

Chairman, G. M. PHELPS, Carnegie Building, Rensselaer Polytechnic Institute, Troy, New York

The problems and specifications for the 1940–41 Competition will be furnished schools interested in the Competition, or desiring to enter contestants. Applications, accompanied by an entry fee of one dollar, should be made to the Chairman of the Competition Committee, who will supply the necessary problem specifications, identification numbers, and cards for listing information concerning the contestant and his instructor. An elimination contest in each school is suggested as a means of selecting the best drawings. We hope that as many schools as possible will see fit to promote the competition by entering drawings.

Drawings will be judged at the annual meeting of the Society in June, 1941. Final date for submitting problems, and the name of the person to whom they should be sent, will be included with the specifications.

Work is limited to the first year (or equivalent) drawing courses. Students in advanced courses, or who have been professionally employed as draftsmen, are not to be entered.

The Competition will be divided into nine classes which will include problems in orthographic size and shape description, working drawings, freehand sketching (pictorial and orthographic), lettering, and a problem involving originality of solution and layout. No student shall be entered in more than one class.

Membership of the National Drawing Committee was announced on this page in the November issue.

MID-YEAR DRAWING CONFERENCE

The Journal of Engineering Drawing announces that, through the courtesy of Dean A. S. Langsdorf and his drawing department staff, the Mid-Year Drawing Conference will be held at Washington University, St. Louis, Missouri, on Saturday, February 22, 1941. The program will afford a contact with industry, where our product is absorbed, and with high school teachers, who provide the preliminary training of much of our raw material.

Further information may be obtained from Dean Langsdorf or from Professor R. P. Hoelscher, University of Illinois.

THE MARKET FOR ENGINEERING SERVICES
1940–1950

American Association of Engineers has just released its findings in a survey of the probable market for engineering services 1940–1950. The estimates are based on a study of employment conditions during the period 1929–1940. Salary trends for the whole profession, and for different classifications with the profession have been determined for each of those years; special consideration has been given to the ratio of permanent and temporary jobs; studies have been made of age restrictions, the operation of the licensure laws, activity in new techniques and technologies; careers of recent graduates have had special attention.

Requirements set up by employers as to qualifications for definite engineering positions have been analyzed to guide engineering educators in order that students may be prepared to meet definite needs.

Interesting sidelights developed in the survey pertain to the oblique effects of labor and social legislation on engineering. Confusion in classification of engineering positions is traced to the inconsistencies of engineering pay in various classifications in federal projects of different kinds—C.C.C., W.P.A. and work relief.

Age restrictions have undergone spasmodic changes since 1929. The period of '36 and '37, when social security legislation was first a factor, exhibited the most restrictive market—with a heavy demand for men under 35—even under 31. The last two years have afforded the best market for men over 40 that has been found since 1929, due to the need of experienced men, and the intermittency of employment during the depression which has made it difficult for the younger men to accumulate the amount and kind of experience needed. The conscription law produced a quick demand for men over 35.

Volume of employment in 1940 is about on a par with volume in 1930, the survey indicates, but salaries in 1940 are 23 per cent below those of 1929, while 1930 salaries were but 5 per cent off the 1929 level.

Copies may be secured from National Headquarters, American Association of Engineers, 8 S. Michigan Ave., Chicago, Ill.

M. E. McIver,
Secretary

BOOK REVIEWS

Business Reports. Second Edition. A. G. SAUNDERS AND C. R. ANDERSON. McGraw-Hill Book Company, Inc. New York and London. 1940. 468 pp. $3.50.

Although *Business Reports* has been written chiefly for men in business and industry, its contents are invaluable for the engineer and the scientist. The book offers many practical suggestions concerning the preparation of clear and effective reports. The authors have incorporated in the 1940 edition—the first edition appeared in 1929—the results of up-to-date business practice as it has developed during the 1930's.

The book is divided into two parts: (1) the technique of investigation of a problem; (2) the technique of presentation of the facts which have been investigated. Taking into consideration the large number of types of reports, the authors have presented one general, basic plan which can be applied to almost all reports. Yet the book does not neglect definition of the conventional types.

Part I deals with the beginning of the investigation, the collection of data, the organization and interpretation of these data, and the drawing up of conclusions and recommendations. Part II helps the tyro to put his report into words which will be most effective in achieving his purpose. The chapters dealing with the preparation of tables and charts and the mechanics for typed work are especially useful.

The authors have performed a noteworthy service in analyzing the technique of the questionnaire and the checking of its results. In addition, they have discussed intelligently the personal interview and the telephone interview. Throughout the book, a nice balance has been preserved between illustrative material and discussion of principles. Illustrations are drawn from actual reports made for business and industry. Excellent samples of letters of authorization and letters of transmittal are included.

Appendixes explain representative statistical tools used in sampling to obtain quantitative information and set down typical outlines of reports. Teachers will welcome the appendixes concerning a suggested outline for a report-writing course, a suggestive list of report subjects, and report-writing problems. These appendixes, plus a bibliography which has amplitude, will be hailed by student, business man, scientist, and teacher.

W. G. CROUCH

Technical Exposition. First Edition. LESLIE M. OLIVER, Associate Professor of English, Colorado School of Mines. McGraw-Hill Book Company, Inc. New York and London. 1940. 184 pages. $1.50.

The sub-title of "Technical Exposition" reads, "A textbook for courses in expository writing for students of engineering." The author has limited the group for which the book was written to students who have had a course in freshman English and who are presumed to know elementary sentence structure and the principles of paragraphing. Notwithstanding, he has included a sketchy chapter on sentence structure and words and phrases improperly used and a brief chapter on the rules of punctuation.

The book is succinct and clear in its discussion of the principles governing the main forms of expository writing, but the contents are so abbreviated that little space is given to necessary illustrative material. Although this lack of illustrations is especially noticeable in Part III, which discusses the business letter, it is apparent in every chapter.

"Technical Exposition" is divided into four parts. Part I covers the qualities of good engineering writing; the conventions which govern such writing; what is meant by effective English; the method of revising papers; and such problems in technical writing as description of a machine, a tool, a device, or an instrument, the making of abstracts, the clear statement of a problem, the explanation of processes, how to give directions, how to discuss basic principles, and how to explain a problem which is capable of being attacked in two different ways. The problems are practical and simply presented.

Part II takes up research papers and reports. Part III sets forth the principles of the modern business letter. And Part IV has a valuable, but brief, discussion of vocabulary and punctuation.

If the book were used in conjunction with a good handbook of composition, it would provide the instructor and the student with a useful manual. Nevertheless, the instructor would have to provide a large number of illustrations in order to guide the student in his work.

Professor Oliver has a lucid, pleasing style. His book is outstanding in this respect. But it needs expansion.

W. G. CROUCH

Principles of Alternating Current Machinery. Third Edition. RALPH R. LAWRENCE. McGraw-Hill Book Company, New York, 1940. 678 pages. $5.50.

The outline of the new third edition is the same as the previous second edition, *i.e.,* Synchronous Alternators; Static Transformers;

Synchronous Motors; Parallel Operation of Alternators; Synchronous Converters; Polyphase Induction Motors; Single Phase Induction Motors; Series and Repulsion Motors. Principles underlying the alternating current machinery of major importance have been included and miscellaneous special types are not emphasized.

Much of the book has been entirely rewritten and much new up-to-date material has been added. The new edition has been improved by the inclusion of more illustrative problems, although there are no problems included for student "home work." For this purpose the author recommends "Problems in Alternating Current Machinery" by W. V. Lyon.

There are 341 figures including connection diagrams, vector diagrams, characteristic curves and other illustrative material. All these are well recognized aids to the student in his efforts to acquire the fundamental principles. The writer has already adopted this book for use with senior electrical engineering students and we like it.

R. C. GORHAM

Stress Analysis and Design of Elementary Structures. JAMES H. CISSEL, University of Michigan. New York: John Wiley & Sons, Inc. 1940. 335 pages. 221 illustrations. $4.00.

The author presents a book unique in its purpose. As indicated in the preface, it is intended primarily "for fields of engineering other than civil, which include a course in structures." With this in mind he has collected the fundamental and practical materials of considerable scope useful to many engineers. However, it is not a voluminous work of unnecessary detail. The prerequisite knowledge is a study of statics and strength of materials.

The book is divided into two main parts. Part I "Stress Analysis" considers forces, loads, graphic statics, shears, moments, continuous beams, trusses, and stability of structures. In Part II "The Design of Simple Structures," chapters include structural fastenings and connections; timber beams and columns; steel beams, girders, and columns; and reinforced concrete beams, slabs and columns. An adequate set of tables of structural data in the appendix eliminate the necessity of an auxiliary handbook.

Of particular merit is the inclusion of a wealth of material on timber connectors. The section on welding rounds out an up-to-date coverage of structural connections. The addition of a chapter dealing with the basic concepts of reinforced concrete design is a new and worthwhile step in such an elementary structures text.

Throughout the book, illustrative problems assist the reader in understanding the subject, while sketches, diagrams, and plates offer visual interpretation.

A. C. ACKENHEIL

G-E Campus News

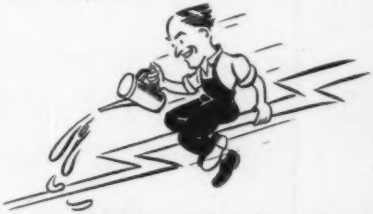
STOP THIEF!

BURGLARS and other criminals can no longer hope that bad radio weather will increase their chances of a getaway by gumming up police radio. Atmospheric disturbances, ignition noises, street car interference—in fact all the reception devils that plague the life of radio police practically disappear with the introduction of frequency modulation, the new method of broadcasting developed by Major E. H. Armstrong. Several two-way FM installations have already been made. One of the first was in Douglas County, Nebraska, which recently installed a number of G-E transmitters and receivers.

Among those responsible for many of the G-E developments which have made two-way FM possible are I. R. Weir (Rose Poly, '21) and H. P. Thomas (Harvard, '25)—transmitter engineers; and W. C. White (Columbia, '12) and K. C. DeWalt (Iowa, '27)—vacuum tube engineers.

GREASED LIGHTNING

THIRTY-ONE hundred revolutions a minute is lightning fast all right. But when a bearing revolving at that speed makes more noise than a boiler factory and coasts to a stop in 12 seconds, then it's time to look for a good lubricant. There's a catch though; the bearing is a part of an x-ray tube and operates in a high vacuum. The tendency of oil and grease to vaporize under these conditions makes it impossible to use ordinary lubricants.



So G. E. X-Ray Corporation engineers Atlee (Oregon State, '29), Filmer (Armour Tech, '31), and Wilson (College of Emporia, '31) set to work and developed a new lubricant—barium. When a thin film of this metal was applied to the bearing, its speed rose to over 3500 rpm, the noise of operation was materially reduced, and the coasting time was increased to eight minutes.

The benefit of these young men's research is not limited to the x-ray field alone, for their findings will apply equally well in all cases where rotating devices operate in a vacuum.

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